THE HIGH SPEED ELECTRONICS GROUP

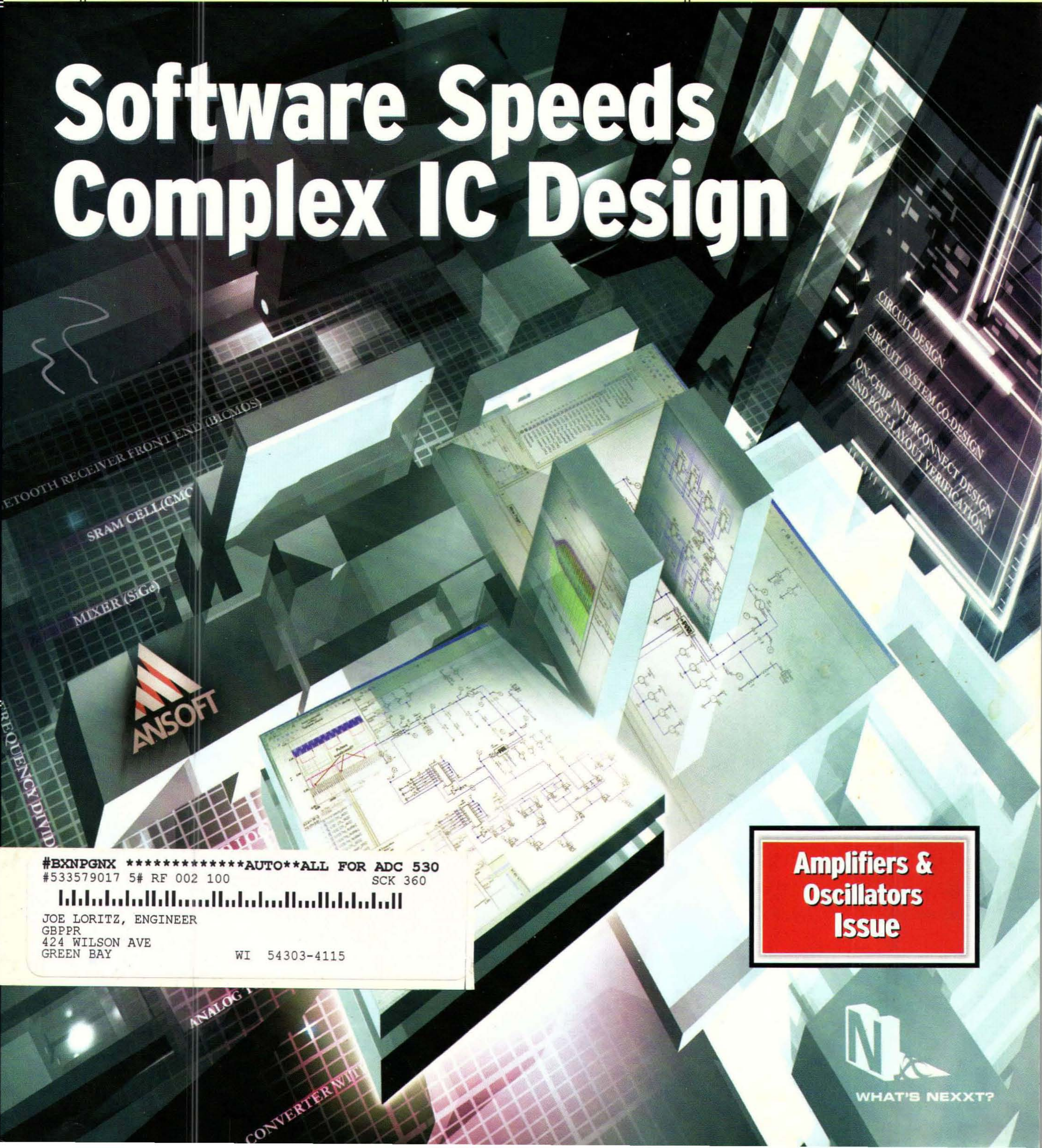
# Microwaves & RF

**News**
Surveying the latest power dividers/combiners

**Design Feature**
Use an ESD-rugged device for automotive LNAs

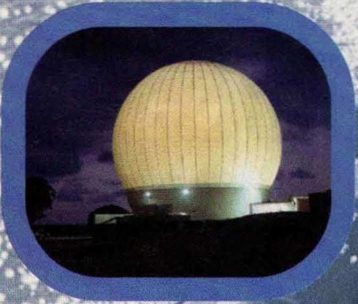
**Product Technology**
Instrument analyzes RF signal sources

# Software Speeds Complex IC Design




**Amplifiers & Oscillators Issue**

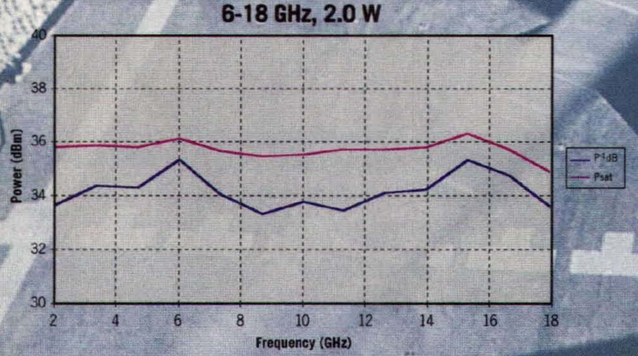
# Bookham JCA™



| Model | Freq. Range GHz | Gain dB min | Flatness +/-dB Max | 1 dB Comp. pt. dBm min | N/F Max | 3rd Order ICP typ | VSWR In/Out Max |
|---|---|---|---|---|---|---|---|
| **LNA's** | | | | | | | |
| JCA12-3001 | 1.0–2.0 | 40 | 1.0 | 10 | **0.8** | 20 | 2.0 |
| JCA24-3002 | 2.0–4.0 | 40 | 1.0 | 10 | **1.0** | 20 | 2.0 |
| JCA48-4001 | 4.0–8.0 | 42 | 1.5 | 15 | **1.0** | 25 | 2.0 |
| JCA812-5001 | 8.0–12.0 | 45 | 1.5 | 10 | **1.5** | 20 | 2.0 |
| JCA1218-5002 | 12.0–18.0 | 48 | 1.5 | 10 | **1.5** | 20 | 2.0 |
| **Ultra Low Noise Amplifiers** | | | | | | | |
| JCA45-306 | 4.5–4.8 | 40 | 0.5 | 10 | **0.5** | 20 | 2.0 |
| JCA45-305 | 4.4–5.1 | 30 | 0.5 | 10 | **0.7** | 20 | 2.0 |
| JCA56-309 | 5.4–5.9 | 30 | 0.5 | 10 | **0.7** | 20 | 2.0 |
| JCA78-306 | 7.25–7.75 | 30 | 0.5 | 10 | **0.7** | 20 | 2.0 |
| JCA12-3040 | 1.2–1.6 | 30 | 0.5 | 10 | **0.7** | 20 | 2.0 |
| **Broadband Power Amplifiers** | | | | | | | |
| JCA618-4001 | **6.0–18.0** | 40 | 1.5 | **33** | 3.0 | 40 | 2.0 |
| JCA218-3002 | 2.0–18.0 | 34 | 2.0 | **27** | 4.0 | 33 | 2.0 |
| JCA218-4002 | 2.0–18.0 | 44 | 2.5 | **27** | 4.0 | 32 | 2.0 |
| JCA218-5002 | 2.0–18.0 | 54 | 2.5 | **27** | 4.0 | 32 | 2.0 |
| JCA218-3001 | 2.0–18.0 | 30 | 2.0 | **25** | 4.0 | 30 | 2.0 |

**Low Phase Noise Amplifiers**

| Carrier Offset | C, X-Band (-dBc/Hz) | Ku-Band (-dBc/Hz) |
|---|---|---|
| 100 Hz | **135** | **125** |
| 1.0 kHz | **145** | **142** |
| 10 kHz | **153** | **150** |
| 100 kHz | **158** | **152** |


- ***Amplifiers***
- ***Digital Optics***
- ***High-Power Laser Diodes***

**Request for quote!** Call, fax, or e-mail.
**Free catalog!** Call today!

*2580 Junction Avenue, San Jose, CA 95134-1902 p: 408 ▪ 324-5700 f: 408 ▪ 324-5705 www.bookhamjca.com e-mail: sales@bookhamjca.com*


No Comparison.
We're not the only RF connector manufacturer who offers commercial-grade connectors at competitive prices.
But ours have something that the others don't: Delta quality.
Instead of cutting quality corners or loosening specifications, we've applied our design skills and Lean Manufacturing processes to provide first-class connectors at economical prices.
Get your copy of our new catalog, or visit our website, to see our MCX, MMCX and E-line brass SMA commercial connectors, along with the rest of our product range (including new 27 GHz SMA types).
WORLDWIDE CONNECTIONS
Our International Operations are expanding soon—watch our website for the news!
DELTA
ELECTRONICS MFG. CORP.
Connect Here.
(978) 927-1060
www.DeltaRF.com

JULY 2004 • VOL. 43 • NO. 7

# Microwaves & RF

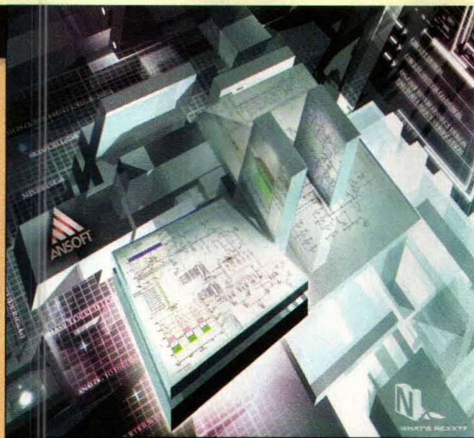
A Penton Publication

Visit us at www.planetee.com

## Departments



Penton



## COVER STORY



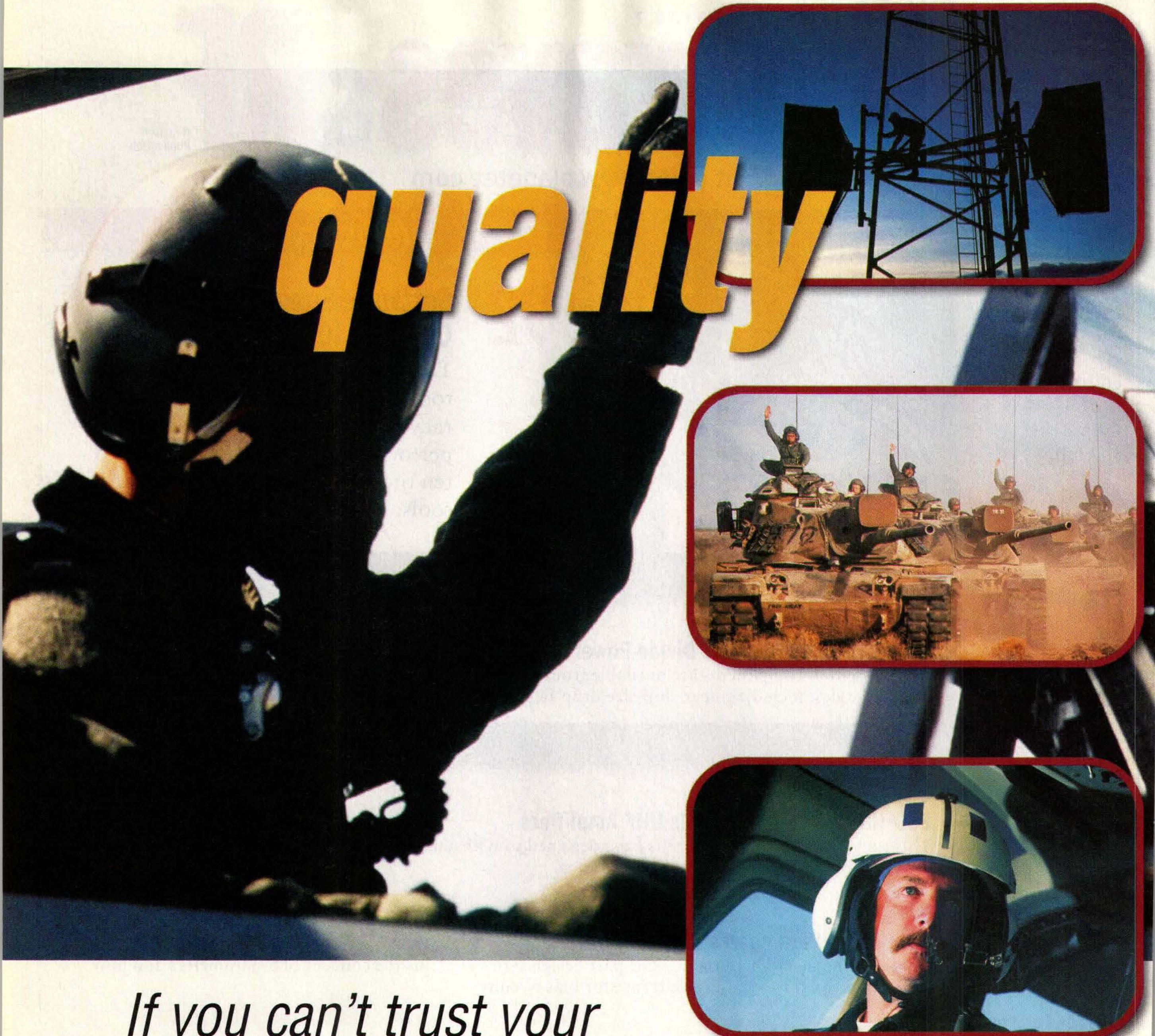
## News



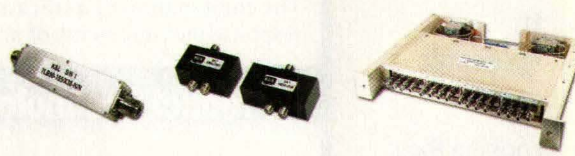
## Design



## Product Technology


quality





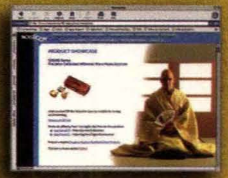
# When you're searching for a higher level of noise calibrations...ask the Masters.

## We can provide you with ultimate accuracy and unsurpassed service.

Noise Com's NBS Series noise calibration standards make it easier and more accurate than ever to calibrate your own noise sources. They can help you eliminate the cost and time of annual calibrations.

The NBS Series calibration standards are the same type used by the NIST, so they deliver lower noise temperature, and greater accuracy and repeatability. Our replaceable horns provide an exceptionally good impedance match too, which reduces VSWR errors, allowing you to expand to multiple frequency ranges in the future.

## 24-hour automated calibration Web page.



Our new automated Web page is simple to use for all your calibration and repair requirements. It quickly and easily provides information and cost for calibration and repairs of noise sources. We can even generate an RMA number for you, online, 24 hours a day. Imagine, instant service anytime, day or night.

When you're looking for answers to your noise calibration needs, ask the Masters of Noise™—Noise Com. Call us at +1 (201) 261-8797. **Or visit our automated site at www.noisecom.com/cal.**

NOISE/COM

A WIRELESS TELECOM GROUP COMPANY

## CHIP INDUCTOR KITS

**0402CS Series**
1.0 nH - 47 nH, 5% tolerance
22 values (10 each) Kit C128 $60

**0603CS Series**
1.6 nH - 390 nH, 5% tolerance
42 values (10 each) Kit C124 $80
Kit C124-2 (2% tolerance) $100

**0805CS Series**
2.8 nH - 820 nH, 5% tolerance
37 values (10 each) Kit C103 $60
Kit C103-2 (2% tolerance) $85

**0805HQ *High Q* Series**
2.5 nH - 51 nH, 5% tolerance
12 values (10 each) Kit C125 $60

**1008CS Series**
10 nH - 4.7 µH, 5% tolerance
36 values (10 each) Kit C100 $100
Kit C100-2 (2% tolerance) $120

**1008HQ *High Q* Series**
3.0 nH - 100 nH, 5%+ 10% tolerance
14 values (10 each) Kit C123 $60
Kit C123-2 (2% tolerance) $80

## AIR CORE INDUCTOR KITS

**Micro Spring™ Series**
Inductance: 1.65 nH - 12.54 nH
9 values (12 each) Kit C108 $50

**Mini Spring™ Series**
Inductance: 2.5 nH - 43 nH
10 values (12 each) Kit C102 $60

**Midi Spring™ Series**
Inductance: 22 nH - 120 nH
10 values (12 each) Kit C118 $60

## POWER WAFER® INDUCTOR KITS

NEW! **LP01704 Power Wafers®**
1.2 µH - 330 µH, 0.13 - 3.6 Amps
16 values (3 each) Kit C142 $60

**LP02506 Power Wafers®**
4.7 µH - 1000 µH, 0.16 - 1.9 Amps
15 values (3 each) Kit C132 (Inboard® versions) $60
Kit C133 (On-Board versions) $60

## POWER INDUCTOR KITS

NEW! **0805PS Shielded Power Chip Series**
1 µH - 330 µH, 0.05 - 0.8 Amps
20 values (6 each) Kit C148 $80

NEW! **1008PS Shielded Power Chip Series**
1 µH - 1,000 µH, 0.11 - 2 Amps
26 values (6 each) Kit C141 $80

**DS1608 Shielded Series**
1 µH - 10,000 µH, 0.02 - 3 Amps
25 values (3 each) Kit C115 $80

**DO1813HC High Current Series**
0.56 µH - 48.1 µH, 0.72 - 6 Amps
9 values (3 each) Kit C131 $60

**DS3316 Shielded Series**
1 µH - 47 µH, 0.8 - 5 Amps
11 values (3 each) Kit C116 $60

**DO3316HC High Current Series**
0.33 µH - 3.3 µH, 6.4 - 16 Amps
7 values (3 each) Kit C126 $45

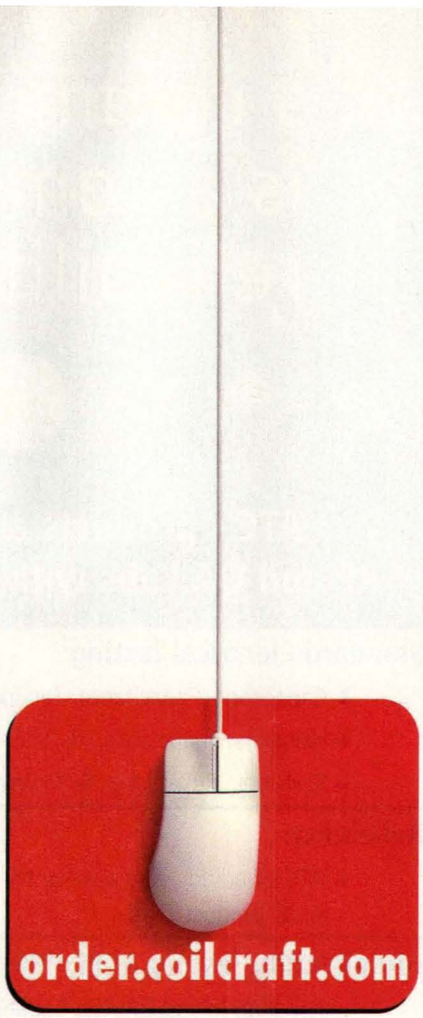
**DO1608/3316 Series**
1 µH - 1000 µH, 0.07 - 6.8 Amps
38 values (3 each) Kit C105 $90

**DS5022 Shielded Series**
10 µH - 1000 µH, 0.53 - 3.9 Amps
13 values (3 each) Kit C117 $60

**DO5022 Series**
1 µH - 1000 µH, 0.56 - 8.6 Amps
17 values (3 each) Kit C111 $60

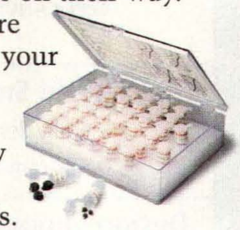
**DO5022HC High Current Series**
0.78 µH - 10 µH, 6.0 - 15 Amps
9 values (3 each) Kit C113 $60

**FOR DOZENS MORE KITS VISIT HTTP://ORDER.COILCRAFT.COM**


# The longest line of magnetics kits is now available on-line

Pull up our web site. Pull out your credit card. And within minutes the kits you need will be on their way.



No one offers more prototyping kits for your RF, EMI and power magnetics. And no one makes it so easy to order, even on nights and weekends.

Of course you can still pick up the phone and call us at **800-322-2645**.

Either way, we'll put the right magnetics right at your fingertips.

Coilcraft®

Cary, IL 60013 800/322-2645 www.coilcraft.com

## Design Feature Corrections

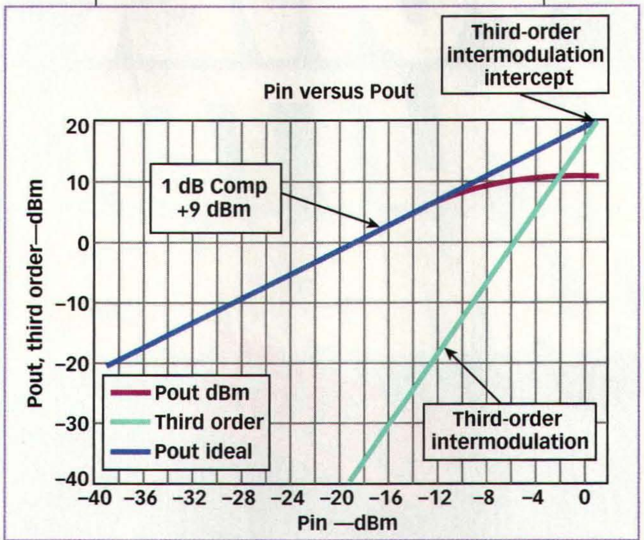
▶▶THE DESIGN FEATURE article that appeared on pages 88 to 98 of the May 2004 issue of *Microwaves & RF* ("Estimate Multiple Carrier Difference" by Howard Hausman) contained at least two errors that are described below.

The first error:

Fig. 1 on p. 88 plots Pout, third-order dBm versus Pin dBm. The light blue curve (line) labeled "Third-order dBm" clearly has a slope of +2 as shown. The third-order intermodulation curve, being a cubic product, should have a slope of +3. The error may be that the ordinate was labeled dBm and should be dBc.

The second error:

On p. 93 at the bottom of the first column, the author incorrectly states, "For system bandwidths less than an octave, even-order intermodulation products are out of band."




Here is a simple counter example of an even-order product that is in-band. For simplicity, consider the less-than-octave band from 10 to 17 GHz. The signals at $F_1$ = 10 GHz and $F_2$ = 16 GHz are in band and their fourth (even) order product $2F_2 - 2F_1$ = 12 GHz is clearly in band.

***Andrew Zeger***

*Howard Hausman responds: Mr. Zeger, thank you for the corrections to my article. Your observations were valid in both areas.*

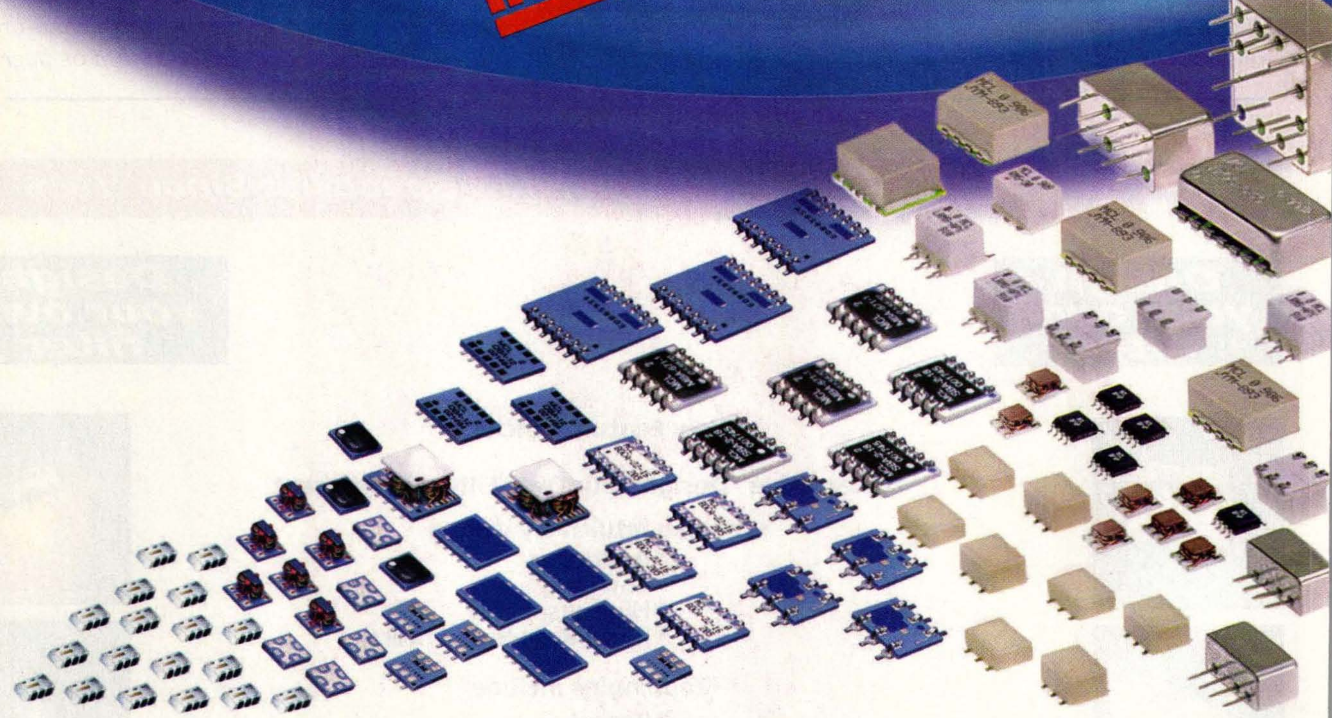
*As per your first observation, The article should have read "second-order intermodulation products" instead of "even-order intermodulation products." With that said, it should be noted that odd-order intercept points are usually a lower level than the surrounding even-order intercept points and, therefore, more of a concern to the systems designer. Typically, the second-order*

*(continued on page 40)*

# THE WORLD'S LARGEST SELECTION

# POWER SPLITTERS/ COMBINERS

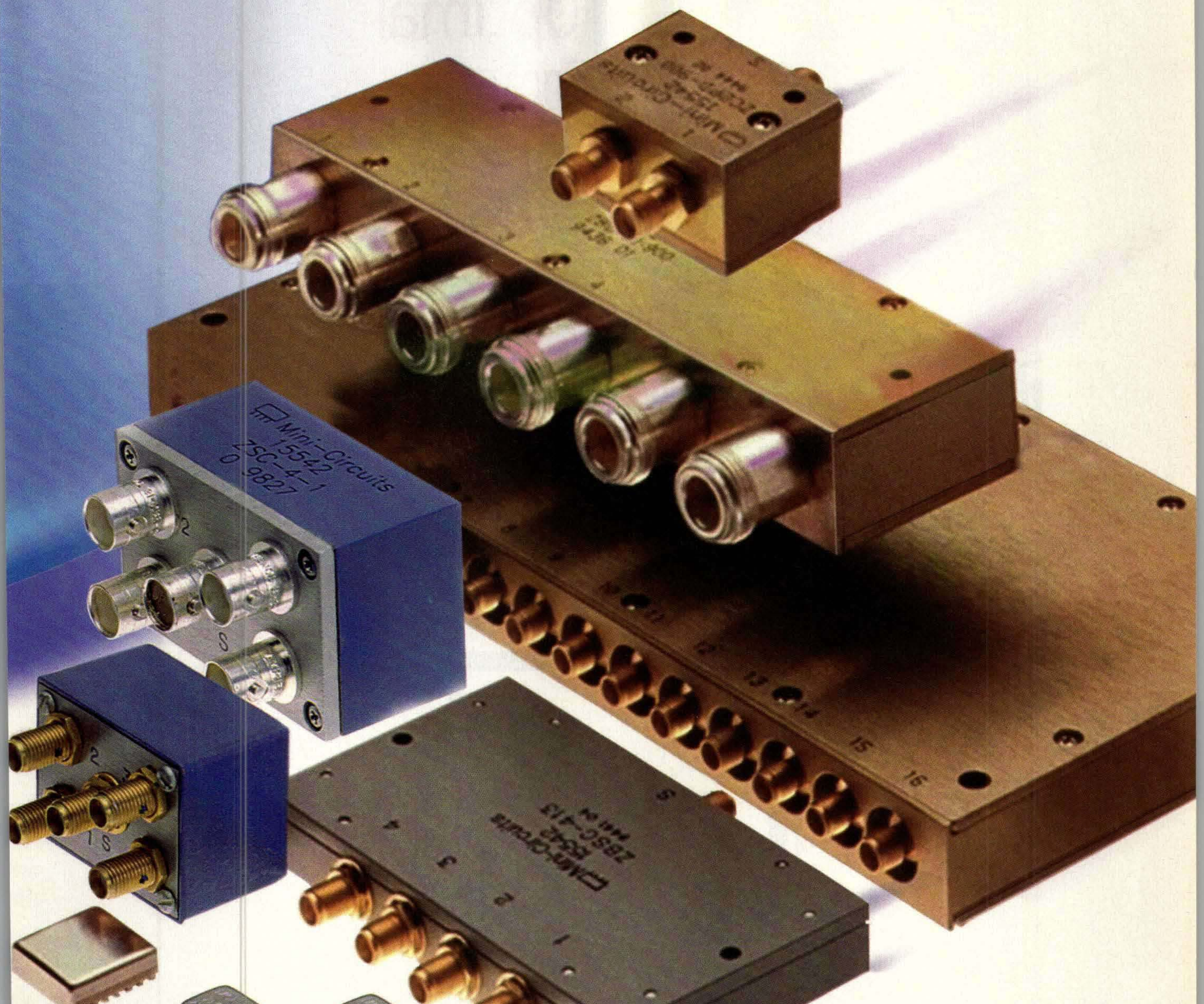
**IN STOCK**



## 2kHz to 12.6GHz from 79¢

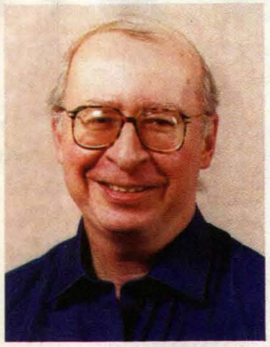
Need just the right surface mount, coaxial, thru mount, or flat pack power splitter or combiner for your project? Mini-Circuits is on the case offering you thousands of high performance, cost-effective models off-the-shelf and immediately available for your military and commercial applications. Choose from 2 and 3way to 48way; 0°, 90°, 180°; 50&75 ohms covering 2kHz to 12.6GHz and beyond, all characterized with detailed data and performance curves available to you in a flash 24/7 on "The Yoni Search Engine" at the Mini-Circuits web site. Surface mount products include highly reliable LTCC designs giving you extremely small size, ultra-low profile, excellent stability over temperature, and high performance repeatability. Tough built coaxial models are available with SMA, BNC, TNC, and Type-N connectors and include broadband ZX10 units standing less than 3/4" in size. And when it comes to your custom needs...just let us know what you're looking for and our development team will go to work! Add our 1 year guarantee, knowledgeable applications support, and value pricing, and the decision is easy. Contact Mini-Circuits today!

***Mini-Circuits...we're redefining what VALUE is all about!***


Mini-Circuits
15542
ZSC-4-1
0 9827
ZBSC-413


BLUE CELL DESIGNER'S HANDBOOK
RF/IF Designer's Guide

# Understanding Specsmanship



POWER DIVIDERS/COMBINERS are considered "essential" components by most amplifier designers. Now available at RF and microwave frequencies in a wide range of packages from roughly 100 suppliers (not to mention distributors), these versatile components allow the combining of multiple power transistors in a high-power-amplifier (HPA), for example, or the splitting of signals two, four, or almost as many ways as desired. A Special Report beginning on page 33 details some of the things to look for when selecting a power combiner/divider.

*Some manufacturers are to be applauded for their efforts to provide as much data (for a comparison) as possible.*

In the midst of poring over hundreds of data sheets of research on power dividers (tirelessly collected and captured from websites by Editorial Assistant Dawn Prior), it became apparent that specifications are not always what they seem. The two obvious examples of this are two of the power divider/combiner "quality" specifications: amplitude unbalance (or balance or tracking) and phase unbalance. While almost every manufacturer standardizes the way they present their own data, comparing data between different manufacturers can sometimes be a challenge. For these two specifications, for instance, many manufacturers choose to present their performance levels in terms of a deviation, such as ±0.3 dB for amplitude unbalance and ±6 deg. for phase unbalance. But just as many manufacturers present these same two specifications as the total range of unbalance, namely, 0.6 dB for amplitude unbalance and 12 deg. for phase unbalance. And in some unfortunate cases, suppliers list what appears like it should have been a deviation, such as ±0.5 dB for amplitude unbalance, as simply 0.5 dB.

Some manufacturers are to be applauded for their efforts to provide as much data (for a comparison) as possible. Mini-Circuits (Brooklyn, NY, www.minicircuits.com), for example, is one of the few power divider/combiner suppliers that include a set of S-parameter data for their components. This data shows values that are considerably higher (certainly not an advantage) than those of competitors, because the data also include division losses (along with the expected insertion loss). While making their products appear to have worse performance (if not properly compared) than a competitor, these data are useful to designers who must consider all losses in a microwave link budget, for example.

Until the industry agrees on a standard format to present data, power divider/combiner specifications (including CW and peak power) must be interpreted before they can be meaningfully compared. But while there is room for interpretation, there is room for specsmanship and unfair comparisons.

Jack Browne

**Publisher/Editor**

# Microwaves & RF

A Penton Publication


Phase-locked Oscillators,
Frequency Synthesizers --
-- EM Research
Featuring the PLXO Series
• Phase Locked Crystal Oscillators
• 5-200 MHz (Fundamental)
• 200-400 MHz (Multiplied)
• 2-50 MHz reference
• Low phase noise –135 dBc/Hz @ 10 KHz (Fout = 70 MHz)
• CMOS outputs available
• Small size, 1.0" square SMT
• Optional Connectorized (1.5" x 2.0")
• Cutting-edge performance, ultra low phase noise and jitter.
• Custom designs available to meet your specific applications.
• High volume and short-run capabilities.
• We ARE your signal source solution!
Typical Performance:
Output Frequency: 50 - 200 MHz (Fundamental) 200 - 400 MHz (Multiplied)
External Reference: 2-50 MHz
Operating Temperature: -30°C to +70°C
Output Power: +7 dBm ±2dB Typical
CMOS Available
Harmonics: ≤ -15 dBc
Sub Harmonics [200-400 MHz]: ≤ -15 dBc
Spurious: ≤ -60 dBc
Phase Noise: (Fout = 70 MHz) ≤ -120 dBc/Hz @1 KHz Offset ≤ -135 dBc/Hz @10 KHz Offset
Supply: +5 thru +12Vdc @ 85mA
RF Connectors: SMT or SMA Female
Lock Range: ±10ppm Typical
Phase Noise:
-135 dBc/Hz
-140 dBc/Hz
-130 dBc/Hz
-140 dBc/Hz
Quality • Consistency
Performance
EM RESEARCH, INC.
2465 Highway 40 • P.O. Box 1247 • Verdi, NV 89439
Phone: (775) 345-2411 • FAX: (775) 345-1030
www.emresearch.com • e-mail: sales@emresearch.com

# the front end

*News items from the communications arena.*

## US MEMS Demand Is Slated To Reach $3.3 Billion In 2008

*CLEVELAND, OH*—The US market for micro-electromechanical systems (MEMS) is projected to increase better than 19 percent per year through 2008 to $3.3 billion **(see table)**. Fueling gains will be further recovery in technology sector business fundamentals, advances in MEMS design and fabrication techniques, and an expanding scope of applications for MEMS-based solutions. MEMS products holding especially good prospects include optical switches for both telecom carrier and internal corporate networks; RF switches and relays for wireless phones and related devices; and advanced actuators such as biochips for complex biomedical testing and analysis. These and other trends are presented in *MEMS Micro-Electromechanical Systems*, a new study from The Freedonia Group, Inc., a Cleveland-based industrial research firm.

**US MEMS market (Millions of dollars)**

| ITEM | 1998 | 2003 | 2008 | %ANNUAL GROWTH 03/98 | %ANNUAL GROWTH 08/03 |
|---|---|---|---|---|---|
| MEMS market by application | 795 | 1370 | 3300 | 11.5 | 19.2 |
| Automotive | 295 | 435 | 875 | 8.1 | 15.0 |
| Information processing | 260 | 390 | 600 | 8.4 | 9.0 |
| Biomedical | 100 | 215 | 525 | 16.5 | 19.5 |
| Telecommunications | 20 | 60 | 450 | 24.6 | 49.6 |
| Consumer | 35 | 75 | 275 | 16.5 | 29.7 |
| Other | 85 | 195 | 575 | 18.1 | 24.1 |



The three best established products within the MEMS market—airbag accelerometers, ink-jet printer heads, and blood-pressure monitoring sensors—are becoming mature, and will register respectable although by no means stellar growth over the next several years. As a result, the strongest gains will occur in new products and emerging applications.

Among end users, the most rapid growth will occur in the telecommunications sector, as MEMS-based optical switching finally begins to gain some commercial traction along with recovery in sector capital spending, and as the market for MEMS-based RF switches and relays continues to develop.

## Laird Technologies' Chris Alderson Is Awarded An MBE

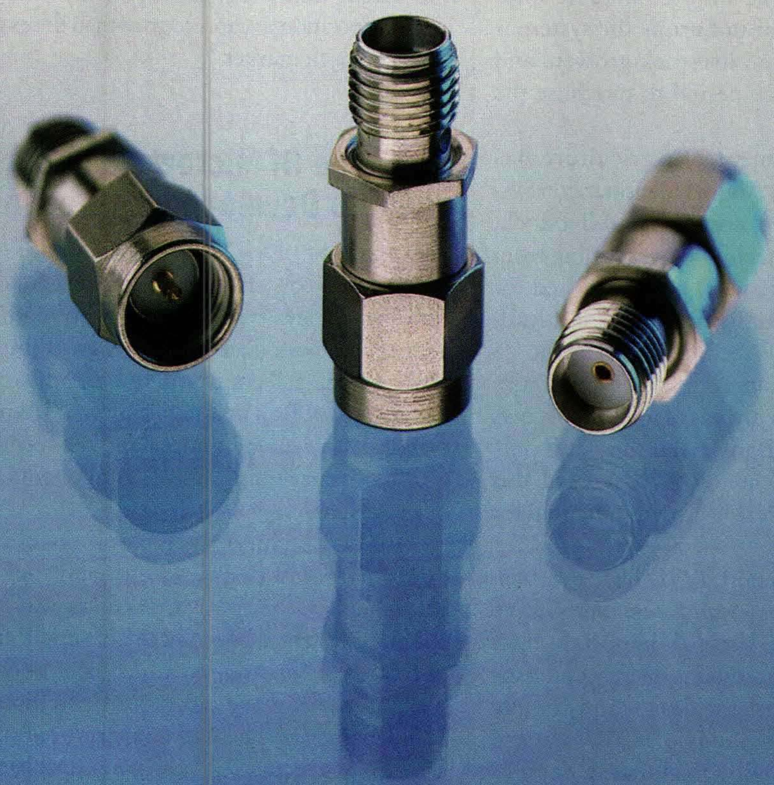
*ST. LOUIS, MO*—Laird Technologies Japan employee, Chris Alderson, has been awarded an MBE (Member of the order of the British Empire) in Queen Elizabeth's Birthday Honors list. The award, for "services to British industry," comes as reward for Alderson's efforts in establishing and developing a successful manufacturing operation in Japan.

In 1999, Alderson was recruited by RFI Shielding Ltd. to set up and run a form-in-place gasket facility, to dispense electrically conductive seals on to small electronic devices, such as mobile phones and PDAs. Alderson developed business relationships with many of the major Japanese electronics giants, including Sony, Panasonic, Sanyo, Kenwood, and Toshiba.

Nippon RFI Shielding KK, of which Alderson was president, became part of Laird Technologies in December 2003, and now employs 30 people at its Yokohama base. Alderson has now taken on a business-development role for the group, covering the whole of the Asia Pacific region.

Philip Mizen, general manager of Laird Technologies UK, states, "Chris is a remarkable young man, extremely gifted and tenacious. This is a just recognition of Chris' skill in successfully introducing a new technology into a notoriously difficult market for foreign companies to break into."

Alderson, 31, is a fluent Japanese speaker and keen follower of Japanese culture. He has been living and working in Japan for the past eight years.



## RFID Will Find A Major Niche As A Livestock Tracker

*OYSTER BAY, NY*—"One RFID market that's gaining a lot of momentum at present is animal tracking," says Sara Shah, an analyst at ABI Research. "Because of the BSE ("mad cow disease") outbreak in Europe, an RFID initiative to track animals was begun there."

When the first cases of BSE were discovered in North America, investigations into their source revealed the lack of any standardized national tracking system for the movements of live cattle, or beef products.

*"One RFID market that's gaining a lot of momentum at present is animal tracking."*

Other countries already have such systems in place. In Australia, a major beef supplier, a mandatory RFID-based National Livestock Identification Scheme has been in place since 2002. Shah says that in Europe the system is still being set up, and livestock growers and vendors have a grace period to purchase the technology.

The US Department of Agriculture has launched a National Animal Identification System (NAIS) to cover most forms of livestock. While a number of technologies ranging from retinal scans to genetic ID are shortlisted for use in such a system, RFID tagging is a leading contender, and is recommended by the US Animal Identification Plan's Beef and Dairy Working Groups. With tens of millions of cows in the US market at any given time, but only an estimated 2 percent now RFID-tagged, this represents a very sizeable growth potential for the RFID market.

ABI Research's report, *RFID Readers: Analysis of Applications, Standards, and Global Markets*, focuses on these all-important links between external data and the internal company network. It examines the design and components of the several kinds of RFID readers, and their integration into a total system. An RFID technology summary details standards, frequencies, and applications.

## RF Micro Devices Completes Acquisition of Silicon Wave

*GREENSBORO, NC*—RF Micro Devices, Inc., a provider of proprietary RF integrated circuits (RF ICs) for wireless-communications applications, announced that it has completed the acquisition of Silicon Wave, Inc., a privately held, San Diego-based supplier of highly integrated Bluetooth solutions for wireless personal area networks (WPANs).

The acquisition of Silicon Wave expands RFMD's total addressable market and is expected to complement its leadership position in handsets. RFMD is currently ramping volume production of Silicon Wave's Bluetooth components for handsets manufactured by a tier-one handset maker. In addition to handsets, the company's Bluetooth products are in use supporting multiple applications, including headsets, printers, and PC peripherals.

Frank Morese, vice president of RFMD's wireless-connectivity business unit, comments, "We're excited to join forces with Silicon Wave to significantly enhance our Bluetooth product portfolio. We believe our combined strengths and unique technology place us in an extremely strong position to capture growth in the explosive Bluetooth market."

## New Type Of Microwave Component Is Developed In Sweden

*UPPSALA, SWEDEN*—The research and development company Racomma has developed a completely new type of microwave component that is anticipated to be of great importance to the telecom and space industries, among others. By a new application of a "smart material," a type of component between traditional passive and active components has been created.

This new technology makes it possible to externally adjust or upgrade not only the software, but also the hardware in microwave circuits and systems. One conceivable application of this is the Earth-based adjustment of hardware in microwave circuits of satellites to compensate for the large temperature fluctuations in space, thereby achieving considerably better performance.

Microwave circuits consist of a metal layer with a specified geometry. Different geometries provide different performance. With this new technique, the geometry, and thereby the circuit's performance, can be changed. Simply put, this is made by a layer consisting of a metal hydride comprising a part of the circuit. By changing the voltage, the metal hydride can be made to switch between a conducting and an insulating state, and then remain in that selected state. The geometry can be changed in such a manner.

## AIT Wireless Acquires Licensing For New Antenna Technology

*LAKELAND, FL*—AIT Wireless, Inc., a distributor office telephone and network systems, has announced that a Letter of Intent has been signed to acquire licensing for the Advance Membrane Transducer Technology from Porrazzo Strategic Technologies through Good Works, Inc.

"This thin membrane transducer technology totally replaces traditional antenna technology; therefore, traditional 'Line of Sight' is not necessary. The potential to enhance the functionality of any electronic device that requires an antenna is profound, including wireless DSL, Point to Point, and Point to Multipoint. We are very excited to be a part of introducing this product through our product and distribution channels," explains Ernest Phillips, vice president of business development for AIT.

*"This product will have broad market implications."*

When asked how confident he was in its performance, Frank Estill, president of AIT, adds, "This technology has been developed and tested in the most rugged of field conditions. Both our armed forces and several unnamed government intelligence agencies have been utilizing this technology in areas of conflict for several years, working with the developers to refine its applications. This product will have broad market implications."

## Kudos

*PALO ALTO, CA*—Agilent Technologies, Inc. announced that it has been recognized for its market leadership by Frost & Sullivan in three areas. Agilent was also named Frost & Sullivan's 2004 Preferred Test and Measurement Vendor of the Year.

Agilent also announced that it has shipped its 800th 93000 system-on-a-chip (SoC) Series tester.

*SHERBROOKE, QUEBEC, CANADA*—C-MAC MicroTechnology has announced TS16949 Certification of C-MAC Microcircuits, Inc., its North American hybrid circuit manufacturing facility, located in Sherbrooke.

*WEST PALM BEACH, FL*—SV Microwave, Inc. is being presented with the Program Executive Office Integrated Warfare Systems (PEO IWS) Excellence Award (the highest US Navy award given to a civilian company), which recognizes top suppliers with exceptional performance in quality, delivery, affordability, and program management.

*POCATELLO, ID*—AMI Semiconductor has been named the ASIC/MMIC/FPGA Commodity Supplier of the Year 2004 by Rockwell Collins.

The Supplier of the Year award is an acknowledgement of significant contributions made during the year by suppliers and is based on delivery, cost of ownership, lead time, and customer metrics.

*MYRTLE BEACH, SC*—AVX Corp. has received recognition from Arrow Electronics, a firm involved in electronics distribution. For the second year in a row, AVX was recognized with the Supplier Excellence of PEMCO Products award. This award named AVX as the passive component supplier that exhibited the best supplier performance for the year 2003.

*WAYNE, NJ*—ANADIGICS, Inc. has been granted patent 6,580,321 for a new active clamping circuit that protects GSM power amplifiers (PAs) from damage under extreme operating conditions. The new clamping circuit is simpler than previous designs and takes up less board real estate.

*BURBANK, CA*—Microfabrica, Inc. has now exceeded 100 US and foreign patents issued or pending.

The patents pertain to the company's EFAB® micro-manufacturing technology, which offers 3D flexibility, ease-of-use, and quick time-to-market in a wide array of applications from wireless electronics to industrial instrumentation.

The patents cover all aspects of EFAB technology, from the basic process to enhancements that make it suitable for certain product segments; pre and post processing steps (including packaging); and novel product design ideas. They also include the inventions of the founding team at the University of Southern California (USC), which are now exclusively licensed to and controlled by Microfabrica.

*KOWLOON, HONG KONG*—Enthone, Inc. has announced that Shenzhen Huamei Electroplating Technology Ltd. was voted as the "Best Brand" in a survey conducted by the Market Information Centre of People Daily (Beijing, China). Specifically, survey participants ranked Huamei Electroplating as having the best electroplating additives in what was the very first "Chinese National Survey on Product Quality and Customer Satisfaction—Corporate (branding)" conducted in mainland China.

*PLAINVIEW, NY*—Aeroflex, Inc. received this year's Frost & Sullivan Award for Growth Strategy Leadership at the 2004 Excellence in Industrial Technology Awards, which were held on May 19 in Miami, FL. MRF

WORLD'S WIDEST SELECTION

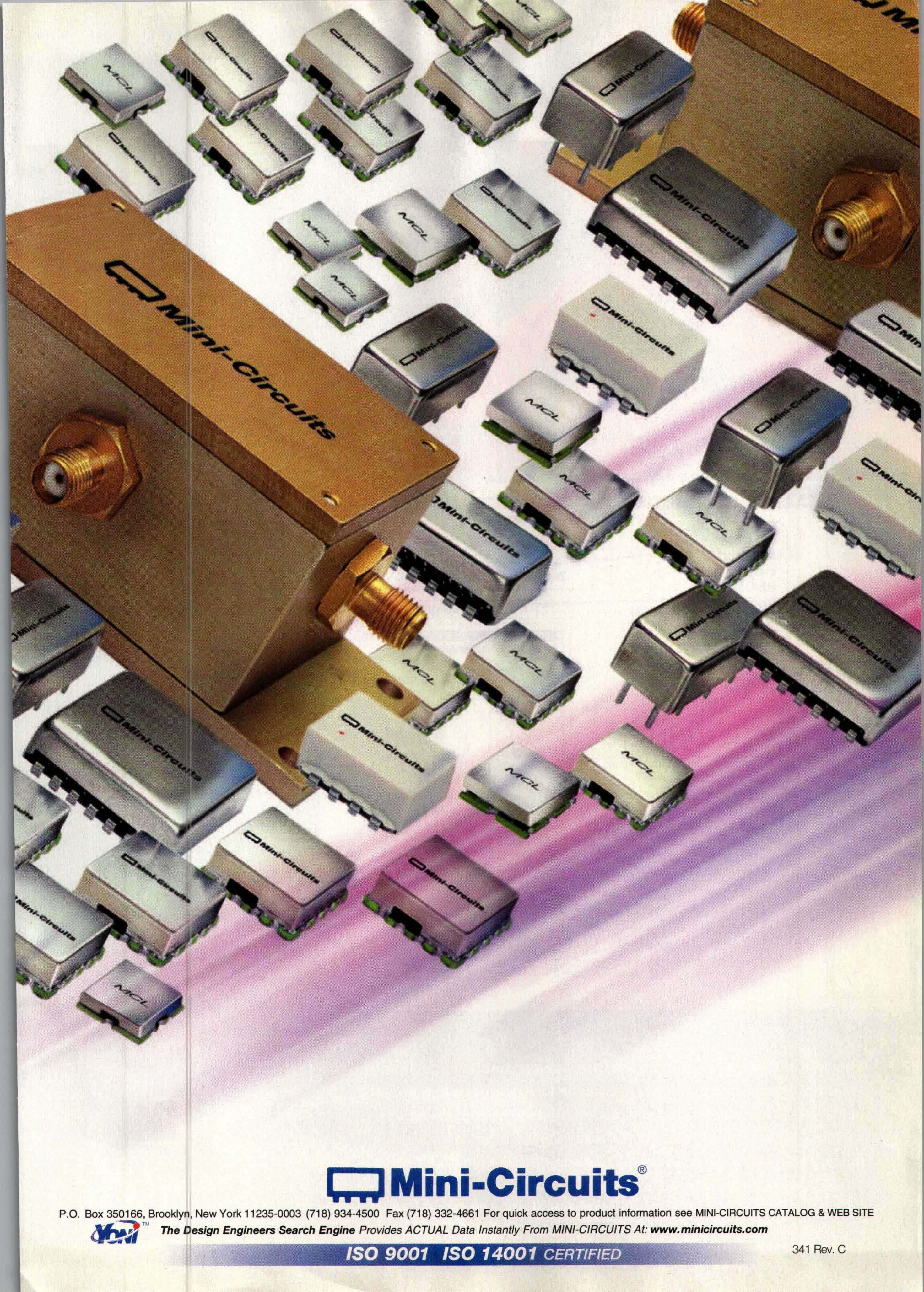

# VCOs

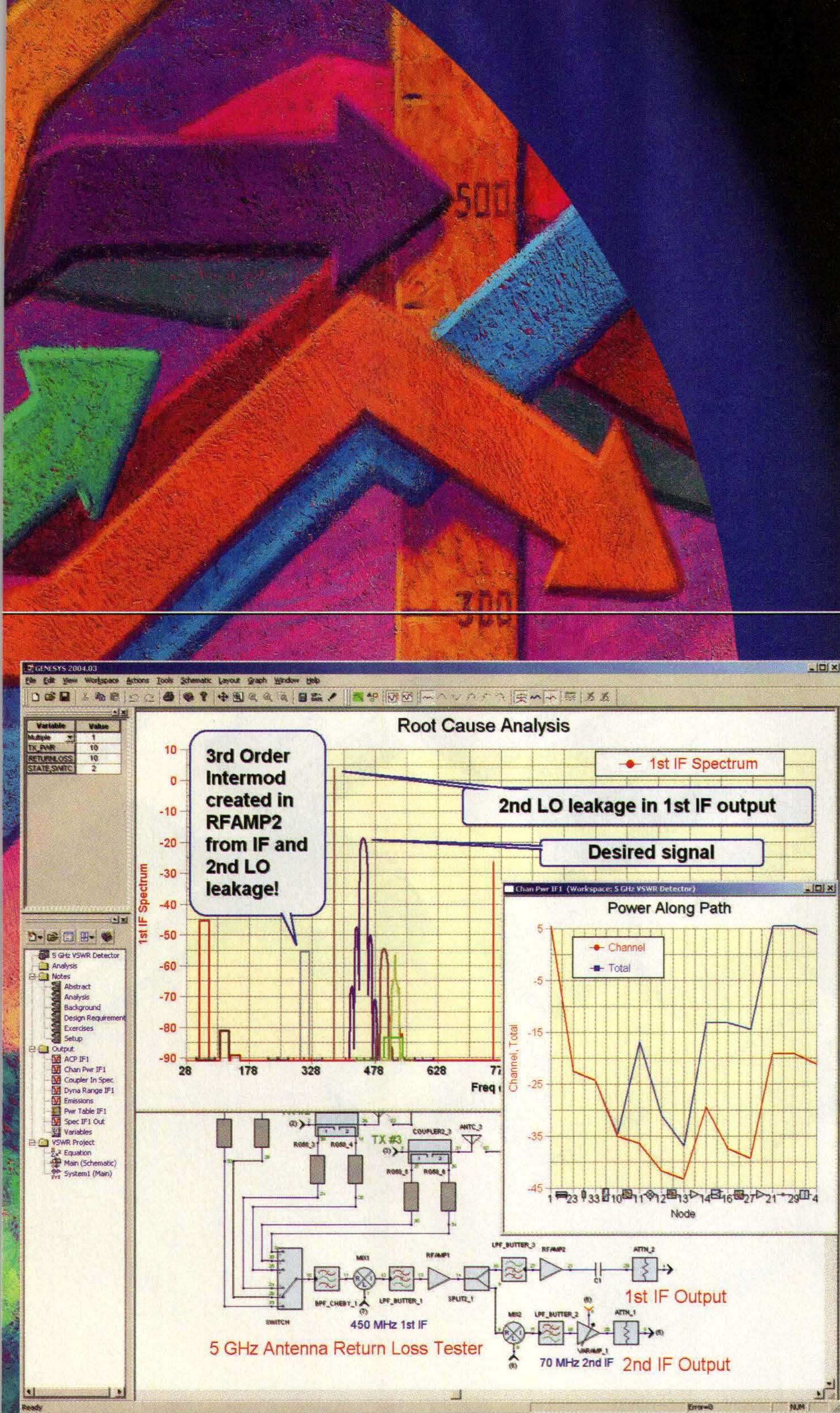
10 to 4400MHz from $11^95 ea. (qty. 5)

Want a miniature surface mount, shielded plug-in, or rugged coaxial voltage controlled oscillator with the right stuff for your project? Contact Mini-Circuits! From custom designs to standard catalog models ***always in stock***, we'll supply extra robust, 100% tested VCO solutions you need at a price you can afford. Choose from narrow to broad to octave band widths. Select linear tuning, low phase noise, and 5V models optimized for PLLs and synthesizers. And pick from an innovative array of miniature SM packages as small as 0.370" square for a variety of designs and applications. You can quickly find the model you need using "The YONI Search Engine" at the Mini-Circuits web site. Just enter your specs...click...and immediately start evaluating suggested VCO solutions using the *actual measured performance data* displayed. But perhaps you need a custom design. Not a problem! Contact us for our lightning fast response, low prices, and quick turnaround. Give the competition *real competition*...specify Mini-Circuits VCOs!


***New VCO Handbook...FREE!***

***Mini-Circuits...we're redefining what VALUE is all about!***


Mini-Circuits®
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE
The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: www.minicircuits.com
ISO 9001 ISO 14001 CERTIFIED
341 Rev. C



Root Cause Analysis
3rd Order Intermod created in RFAMP2 from IF and 2nd LO leakage!
1st IF Spectrum
2nd LO leakage in 1st IF output
Desired signal
Power Along Path
Channel
Total
Node
1st IF Output
2nd IF Output
450 MHz 1st IF
70 MHz 2nd IF
5 GHz Antenna Return Loss Tester

NEWS

# Choosing To Combine Or Divide Power

These essential components are available from a large number of suppliers in a variety of forms and package styles, including near chip-size drop-in power dividers/combiners.

**JACK BROWNE**
**Publisher/Editor**

**Power must often be combined from multiple transistors in an amplifier or antennas in a system, or divided among channels in a receiver. For that reason, the humble RF/microwave power dividers/combiners is among the most competitive product areas in this industry, with about 100 different suppliers. To make an educated decision when specifying a power divider/combiner, it may help to** review the basics of these components along with their key performance parameters before reviewing some of the latest product offerings in this area.

The simplest power divider is a component that splits one input signal into two in-phase output signals. More complex units can be constructed from cascades of this binary configuration, with even-numbered output ports, although dividers with an odd number of output ports, such as a three-way divider, are not uncommon (and often referred to as N-way power dividers, with N equal to an odd number). Power dividers can be formed by internally terminating a 180-deg. hybrid or through the use of Wilkinson or tapered-line configurations. Wilkinson dividers can be realized in microstrip or stripline technologies as a series of cascaded quarter-wavelength transformers. The transformers are used to transform the input impedance, typically 50 Ω, to an output impedance represented by the parallel combination of multiple outputs.

The simplest Wilkinson power divider is a single-section component with 50-Ω input port, two 70.7-Ω quarter-wavelength transformers, and a 100-Ω resistor. This simple configuration is relatively limited in bandwidth; more transformer sections and isolation resistors are needed for increased bandwidth, although the increased complexity also leads to increased size and insertion loss. An excellent application note from M/A-COM (www.macom.com), entitled simply "Power Dividers/Combiners" (application note M561) offers a concise four-page summary of power divider/combiner technology and the importance of various performance characteristics.

In an ideal two-way power divider, a 2-W input signal would result in two 1-W output signals. But resistors and terminations are not without loss, and even the best power dividers suffer some amount of insertion loss from input to output. Insertion loss can be readily calculated for a component as equal to 10log(input power/output power). In comparing power divider/combiner specifications, it should be pointed out that the actual insertion loss in a two-way divider would be comprised of the

3-dB division loss as well as the dissipative losses but, in most cases, manufacturers assume these division losses and present the insertion loss as that value above the nominal division loss (such as 3 dB in a two-way divider and 6 dB in a four-way divider).

Ideally, that two-way power divider would feature two output ports that are infinitely isolated from each other so that the division of power from the input to the output occurs without unwanted signal leakage between ports. In the real world, however, the isolation is limited by variations in component values, manufacturing tolerances, and other factors. Still, high isolation is a measure of a high-quality power divider/combiner, typically exceeding 20 dB. As with insertion loss, the value of a power divider/combiner's isolation will vary with frequency, generally degrading with higher frequencies.


Two additional specifications that are important to power divider/combiner specifiers are amplitude balance (or unbalance) and phase balance (or unbalance). The two terms are also often denoted as amplitude tracking and phase tracking, although they represent simply the differences in amplitude and phase, respectively, between the output ports of a divider. Amplitude unbalance can be almost negligible in a two-way power divider/combiner, with performance levels of ±0.3 dB or less not unusual. As the complexity of a divider/combiner increases, however, this specification tends to increase. An eight-way power divider/combiner, for example, would more typically exhibit amplitude unbalance of ±10 dB between ports.

Phase unbalance will always be the larger number of the two parameters, since it is more difficult to control especially over wide frequency ranges. The small sizes of the latest drop-in and surface-mount power dividers/combiners, however, account for some impressive specifications. Traditional coaxial power dividers/combiners might show a phase unbalance specification of ±10 deg. depending on bandwidth and frequency, with the value increasing as a function of increasing frequency and bandwidth. Drop-in power dividers/combiners such as the Xinger™ line of miniature components from Anaren Microwave (www.anaren.com) achieve good amplitude and phase tracking between output ports through their small sizes and well-controlled manufacturing tolerances. The company's model 4A1305 is a two-way, in-phase power divider that measures 0.560 × 0.350 × 0.081 in. and operates from 1400 to 2600 MHz. It features broadband phase balance of 2.5 deg. with

narrowband performance of 2.0 deg.

Such small power dividers/combiners are available from an increasing number of suppliers, including Merrimac Industries (www.merrimacind.com), Mini-Circuits (www.minicircuits.com), and Synergy Microwave (www.synergymwave.com). The newest power divider from Synergy Microwave, for example, is the model SPD-5-1000, a surface-mount four-way unit measuring just 0.8 × 0.3 × 0.2 in. It features an operating-frequency range of 5 to 1000 MHz with typical insertion loss of 0.7 dB from 5 to 50 MHz, 0.65 dB from 50 to 500 MHz, and 0.7 dB from 500 to 1000 MHz. Isolation is typically 23 dB at the higher frequencies and 27 dB at the low end. Maximum amplitude unbalance is 0.5 dB while maximum phase unbalance is 5 deg. The model SPD-5-1000 divider is designed to handle input power levels to 1 W. The company also offers power dividers/combiners in a variety of package types, including relay headers, leaded and leadless surface-mount packages, and large coaxial packages.

Merrimac's Multi-Mix microtechnology has been applied to the development of a series of miniature power dividers/combiners known as the Pico™ line. The company's Pico Z-series power dividers/combiners are fusion-bonded multilayer stripline assemblies that can be supplied in tape-and-reel format for surface-mount applications. In particular, the model PDD-2Z-1.7G is a two-way power divider/combiner that operates from 1.5 to 1.8 GHz with low loss and reasonable isolation.

Mini-Circuits, which offers one of the most extensive component lines in the industry, also supplies a tremendous variety of power dividers/combiners, including surface-mount and drop-in 50- and 75-Ω components and larger, higher-power coaxial units. The model SBB-2-23, for example, is a two-way surface-mount power divider/combiner that covers 2000 to 2300 MHz and measures just 0.2 × 0.275 × 0.070 in. In spite of the small size, it achieves better than 20 dB isolation across its operating range with phase unbalance of better than 1 deg. When used as a power divider, the tiny component can handle 10 W power, although it is rated for internal (resistive) dissipation of 0.25 W. In contrast, the firm's model ZB4CS-700-10W power divider/combiner is a four-way coaxial unit that is rated for maximum internal power dissipation of 8 W. It operates from 400 to 700 MHz with impressive typical isolation of 25 dB and typical insertion loss of 0.35 dB. (The company's date sheets are among the few in the industry that show actual S-parameters for insertion loss, indicat-

ing the insertion loss with division losses included.)

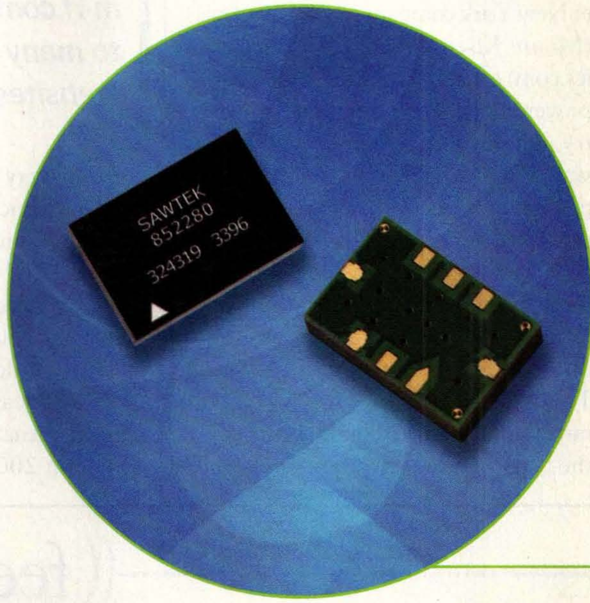
It should be noted that manufacturers often present both amplitude unbalance and phase unbalance in several formats, including as a simple value representing a range, such as 0.5 dB or 6 deg., or as a deviation, such as ±0.4 dB or ±5 deg. It is important to recognize the format used by a given manufacturer and to "normalize" the specifications when performing a side-by-side comparison.

Additional specifications to compare when specifying power dividers/combiners include VSWR and power-handling capability. VSWR, or voltage standing wave ratio, is a measure of how well a component's input and output ports are matched to each other and to the outside world which, in high-frequency systems, is usually at a characteristic impedance of 50 Ω. [Of course, for cable-television (CATV) applications, the characteristic impedance is 75 Ω.] Simply put, the best-matched components will exhibit the lowest VSWR. As with many specifications, manufacturers often list both maximum and typical numbers, with values that vary as a function of frequency. In general, maximum VSWR numbers that are below 2.0:1 indicate good-quality materials and manufacturing processes, especially for broadband components. For example, four-way power dividers/combiners from ARRA (www.arra.com) with SMA connectors are available in frequency bands from 0.005 to 18.0 GHz. One of the company's broadest-frequency components in this line covers a range of 8 to 18 GHz with maximum insertion loss of 1 dB and minimum isolation of 17 dB. In spite of the wide frequency range, the maximum VSWR is a respectable 1.60:1.

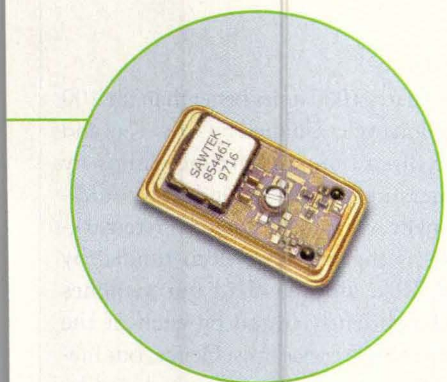
Power-handling capability is a function of several factors, including the physical size of the component (and its ability to dissipate heat), the type of connectors, and how well the ports are matched. Obviously, a rugged coaxial power divider/combiner with machined aluminum housing will be able to dissipate more heat than a chip-sized drop-in or surface-mount power divider/combiner.

In terms of power, most manufacturers provide two levels of capability, average (continuous) power and peak (short-duration) power. The SMA four-way power dividers/combiners from ARRA, for example, are rated for 20 W average power but 1 kW peak power. ARRA, as with most manufacturers, presents these values based on the assumption that all ports are matched (output ports terminated in 50 Ω for a precisely balanced load). Under unmatched conditions, the limiting factor on a power divider/combiner's power-handling capability will be the ratings of the internal resistors (which are rated for about 0.5 W in the case of the ARRA four-way SMA units).

For nearly 40 years, Werlatone (Brewster, NY, www.werlatone.com) has been a company synonomous with high-power passive components. The company offers an extensive line of very high-power dividers/combiners with *continuous* power ratings in the kW range. The company's model D3897, for example, is a two-way divider/combiner that operates from



SAWTEK
852280
324319 3396

SAWTEK
854461
9716




500 to 1000 MHz with a power rating of 1 kW CW. To achieve this, the rugged design employs Type N connectors and achieves maximum insertion loss of 0.2 dB. The component also boasts impressive numbers for amplitude and phase unbalance, at 0.3 dB and 3 deg. maximum, respectively.

In terms of sheer bandwidth, another New York company, RLC Electronics (Mount Kisco, NY, www.rlcelectronics.com) offers some of the widest-range power dividers/combiners in the industry. The new model D-0640-W two-way power divider/combiner, for example, is a multisection Wilkinson design that ranges from 6 to 40 GHz with 15-dB minimum isolation and 1-dB maximum insertion loss. Over the broad range, the amplitude unbalance is ±0.5 dB while the phase unbalance is ±15 deg. The component is supplied with 2.92-mm K connectors to continuously cover the broad frequency range.

Using the same type of connectors, the model 4318-4 from Narda Microwave (www.nardamicrowave.com) is a four-way power divider/combiner with frequency range of 18 to 40 GHz. With maximum input/output VSWR of 1.90:1 and minimum isolation of 14 dB, the rugged component is a Wilkinson-type divider/combiner that is suitable for outdoor commercial and military applications. The 50-year-old high-frequency firm (see *Microwaves & RF*, June 2004, p. 33) offers a wide range of power dividers/combiners, from simple two-way models to more complex 12- and 16-way units. The company has supplied higher-order dividers through 48-way and 64-way dividers with every type of connector from tiny 1.85-mm connectors through rugged EIA 7/16 high-power connectors.

**[ *Visit the Microwaves & RF Product Data Directory website at www.m-rf.com for active links to many of the suppliers' websites.* ]**

The scope of this article prohibits listing all hundred or so suppliers of RF/microwave power dividers/combiners. Those wishing a representative listing are advised to visit the Microwaves & RF Product Data Directory website at www.m-rf.com, click on the Visitors button, log in (or skip log in for quicker access to the site), click on the "Search Manufacturers by Product Category" button, click on the "Components" menu selection, then select either the "Power Combiners" or "Power Dividers" category for an extensive listing of suppliers, many with active links to their websites. MRF

# (( feedback ))

*(continued from page 13)*

*intercept point is 10 dB above the third intercept point and the fourth-order intercept is above second- through fifth-order intercept points. It follows from this line of thinking that after considering third-order intermodulation products, the next-highest intermodulation product is usually the fifth-order when considering secondary effects. Even when considering tertiary effects, the systems designer will analyze seventh-order intermodulation effects before considering fourth-order intermodulation effects.*

*With respect to your second comment, as you stated the third-order intermodulation line in Fig. 1 in the article was incorrect. The slope of the third-order intermodulation interference should be 3:1 instead of 2:1. The corrected figure is shown on p. 13. The error was in the drawing of the graph. The analysis presented, including the charts, is correct.*

## MEMS And The MTT-S Show

▶▶I WAS VERY intrigued to see your Editorial in the June issue of *Microwaves & RF* about MEMS at the MTT-S in Fort Worth ("MEMS Make Noise At MTT-S," p. 17), and I was shocked not to see mention of our company, Radant MEMS, Inc. We, like Dow Key, had an exhibit at the show, but we were down in the "hockey arena" area at booth 283. This was our first appearance as an exhibitor at MTT, and we were there to introduce our company to the marketplace as well as offer MEMS switches that are now in full production in a wafer-level package. Radant MEMS has been developing MEMS RF switches for the last two years, and these switches have a demonstrated lifetime exceeding 100 billion cycles.

That is 1000 times better than the 100 million cycles claimed by Dow Key and the often omitted lifetime claims by others in the MEMS industry. Additionally, what makes this claim remarkable is that we have been funded by DARPA, who has had our switches independently tested by each of the three DoD service labs. Hence, our lifetime results have been reproduced by the Air Force Research Lab, the Army Research Lab, as well as the Naval Research Lab at each of their respective locales. Many military and commercial applications, such as phase shifters for radar or band-select switches for GSM cell phones require lifetimes on the order of 100 billion cycles, making the 100 million cycle switch far inferior.

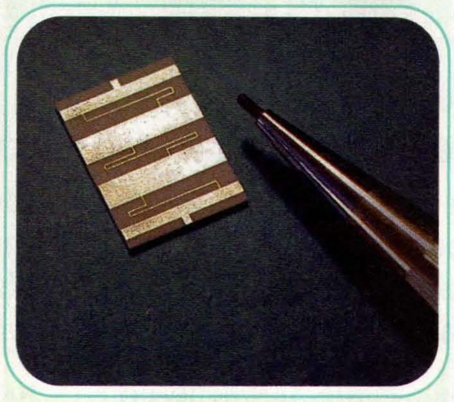
***John Maciel***
Vice President and Chief Operating Officer
Radant MEMS, Inc.
Manager, Electromagnetics Technology
Radant Technologies, Inc.

## System Evaluates Next-Generation Wafers

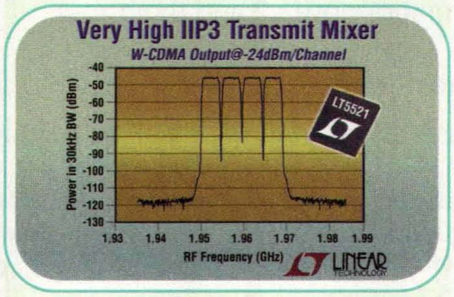
DESIGNED FOR a wide range of current-voltage (I-V) and capacitance-voltage (C-V) on-wafer measurements on CMOS, bipolar, and GaAs integrated circuits (ICs), the model S470 is a ready-to-run parametric test system with RF test options to 40 GHz. The Model S470 bundled system comes in a 24-pin configuration, including probe card adapter and cabling, with full guarding and Kelvin connections to the probe needles. The versatile KTE software runs on a Sun controller using the Solaris UNIX operating system. Standard CMOS and BiCMOS measurement libraries are included, and new algorithms can be created with the included C-language compiler. On-site system installation and one-year warranty are included.

**Keithley Instruments, Inc., 28775 Aurora Rd., Cleveland, OH 44139-1891; (888) 534-8453, (440) 248-0400, FAX: (440) 248-6168, e-mail: product_info@keithley.com, Internet: www.keithley.com.**

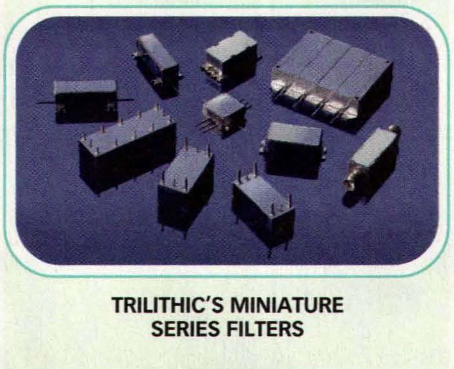

**KEITHLEY'S MODEL S470 PARAMETRIC TEST SYSTEM**



**INTERNATIONAL MANUFACTURING SERVICE'S BANDPASS FILTER**




**LINEAR TECHNOLOGY'S LT5521 ACTIVE MIXER**



**TRILITHIC'S MINIATURE SERIES FILTERS**

## Drop-In Filter Passes 950 To 1450 MHz

COMPACT IN SIZE but not lacking in performance, a miniature bandpass filter has been developed for drop-in applications around 1200 MHz. With a passband of 1200 ± 250 MHz, the planar filter features at least 25 dB rejection at 2.5 GHz with at least as much rejection through 4.6 GHz. The miniature filter, which measures only 0.55 × 0.44 × 0.25 in., achieves a VSWR of 1.0:1 over a 20-percent bandwidth. The insertion loss over the entire passband is a low 0.5 dB. The filter's design incorporates lumped/distributed parameters, is bilaterally symmetric, and contains seven sections with input and output ports matched to 50 Ω. The company offers similar filter configurations for a variety of custom frequency ranges and electrical requirements.

**International Manufacturing Services, Inc., 50 Schoolhouse Lane, Portsmouth, RI 02871; (401) 683-9700, FAX: (401) 683-5571, e-mail: sales@ims-resistors.com, Internet: www.ims-resistors.com.**

## Active Mixer Simplifies 3G Base-Station Design

DEVELOPED FOR third-generation (3G) cellular base stations, the LT5521 active mixer offers a wide frequency range from 10 MHz to 3.7 GHz, and operates with low local-oscillator (LO) drive level of only –5 dBm. Not only does this reduce LO radiation within the base station, it also controls LO-to-RF leakage to a low –42 dBm. The LT5521 operates with a single-ended LO drive and runs on a single supply voltage of +3.15 to +5.25 VDC. The conversion loss is a negligible 0.5 dB, with low noise figure. The LT5521 is supplied in a 16-pin 4 × 4-mm surface mount quad-flat-pack (QFP) housing. The mixer is suitable for applications in wideband CDMA, UMTS, GSM, and PHS base-station transmitters. P&A: $4.95 (1000 qty.); stock.

**Linear Technology Corp., 1630 McCarthy Blvd., Milpitas, CA 95035-7417; (408) 432-1900, Internet: www.linear.com.**

## Rugged Filters Screen 10 MHz To 3.5 GHz

TINY FILTERS in the Miniature Series deliver high-performance characteristics such as high quality factor (Q) and low insertion loss in footprints much smaller than conventional tubular and LC-type filters. Models range from very low-cost TO-8 and surface-mount types to hi-rel and space-qualified models that can be screened for shock, vibration, acceleration to 50 g, wide temperature cycling, resistance to corrosion, and fine leak tests. Filter response characteristics include Chebyshev, Butterworth, Bessel, linear phase, Gaussian, and elliptic responses. Filter topology can be customized to deliver increased rejection on the low side of the passband or arithmetically symmetric rejection around the passband. Up to 12 sections can be incorporated, depending on the package style. Nearly all package styles (more than 17 standard types) can be hermetically sealed.

**Trilithic, Inc., 9710 Park Davis Dr., Indianapolis, IN 46235, (317) 895-3600, Internet: www.trilithic.com.**


Ceramic Resonator
Oscillators CHALLENGE
SAW Performance
PHASE NOISE
CSO Series @ 2488.32 MHz
SAW @ 2488.32 MHz
FEATURES:
• Low / Uniform Thermal Drift
• Small Size, Surface Mount
• Exceptional Phase Noise
+ 100°C
CSO SERIES
SAW
TEMPERATURE
- 40°C
New
SYNERGY
MICROWAVE CORPORATION
CSO Series
$AW
C$O
CSO SERIES
622.08
SAW
2488.32
FREQUENCY
For Additional Information,
Contact Synergy's Sales and Application Team.
201 McLean Boulevard, Paterson, NJ 07504
Phone: (973) 881-8800 Fax: (973) 881-8361
E-mail: sales@synergymwave.com
Website: www.synergymwave.com
SYNERGY®
MICROWAVE CORPORATION

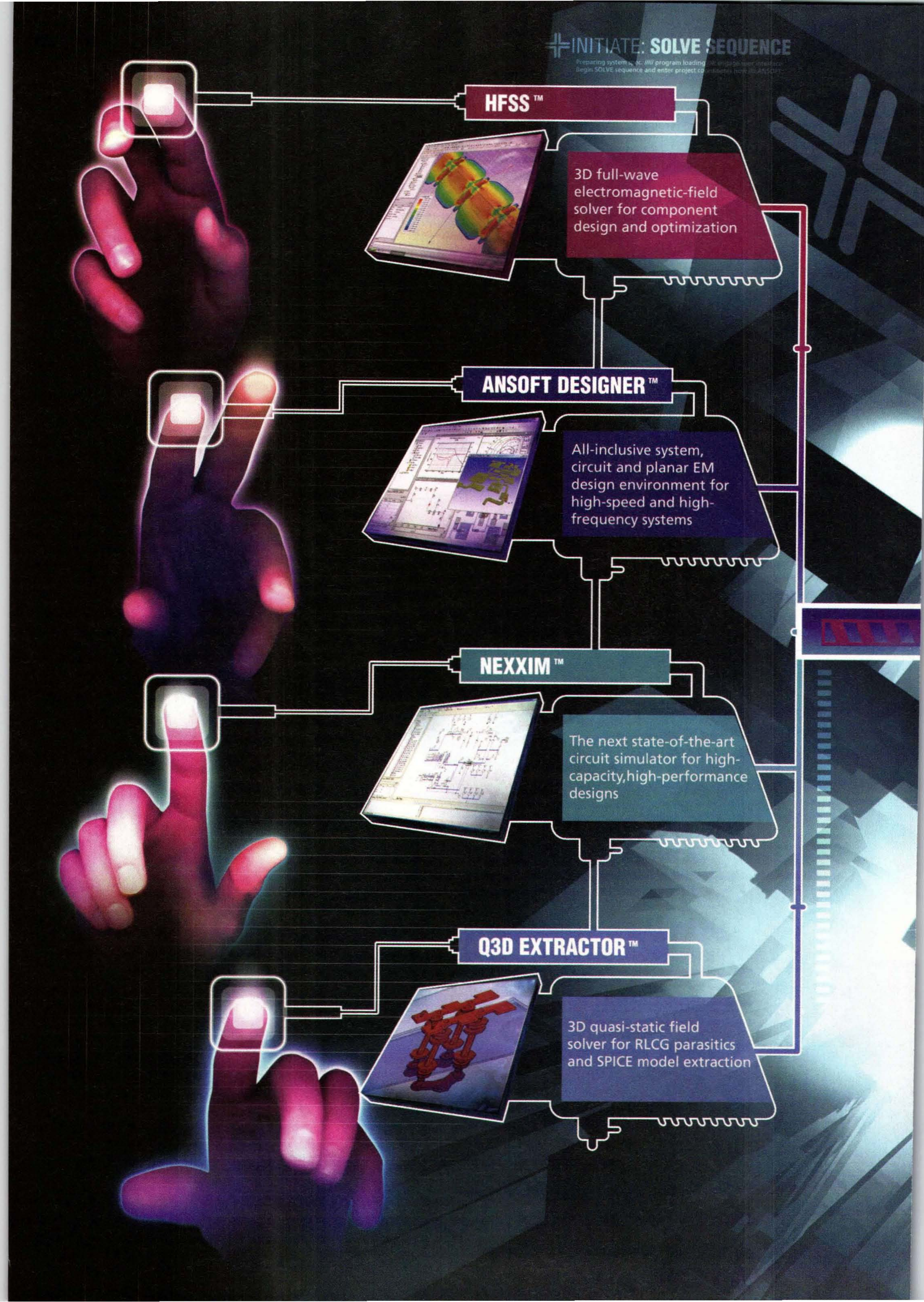
# Dielectric Labs Acquires Voltronics

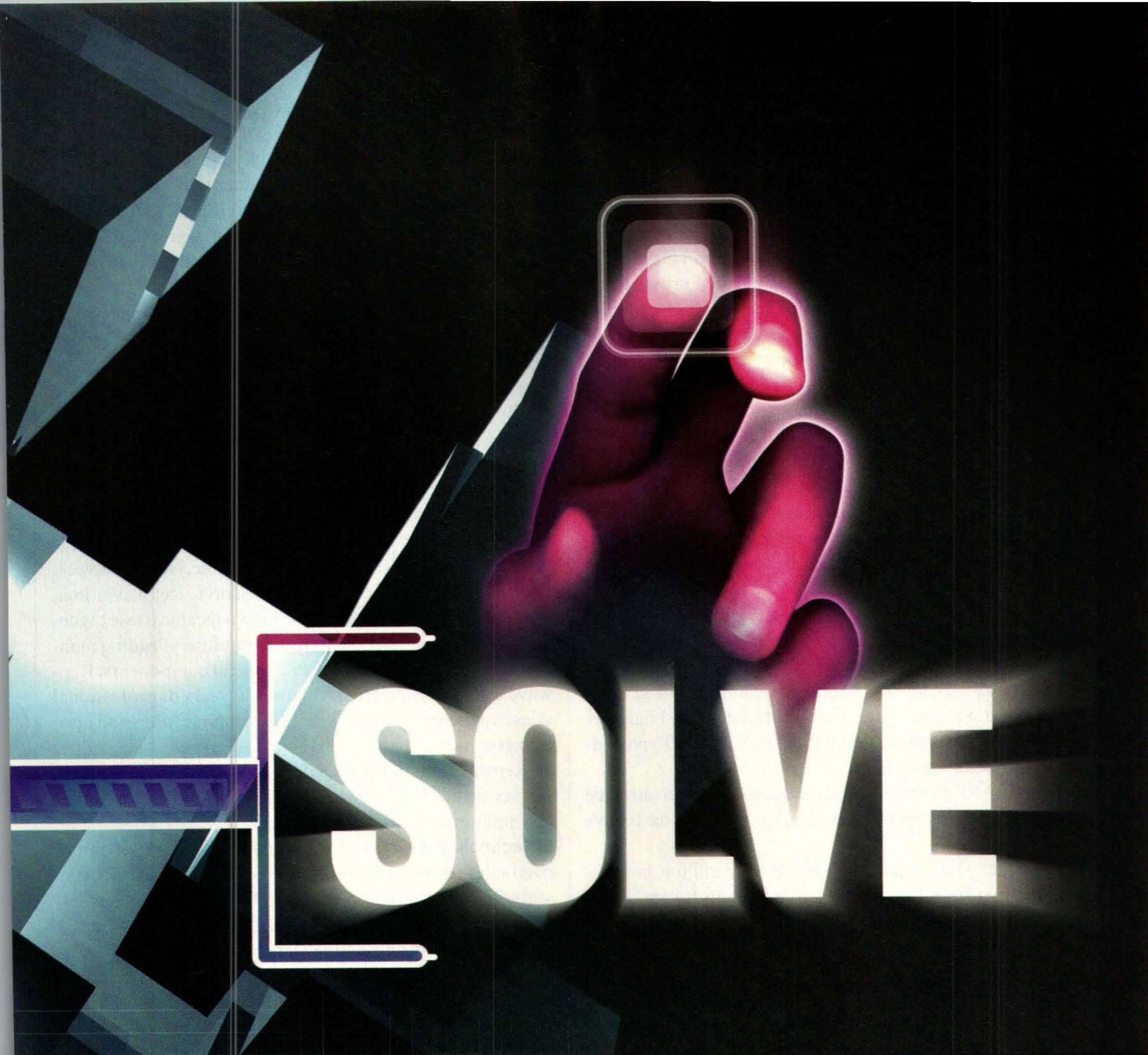
DIELECTRIC LABORATORIES (Cazenovia, NY) has announced the acquisition of Voltronics Corp. (Denville, NJ). Both firms manufacture microwave capacitors—Dielectric Labs (www.dilabs.com) is known for its fixed-value products and Voltronics (www.voltronicscorp.com) for its variable (trimmer) capacitors, including non-magnetic components used widely throughout the medical diagnostics industry. Brian DuPell, president of Dielectric Labs, comments, "We are pleased to have Voltronics among the Dover family of companies (www.dovercorporation.com). Although Voltronics will conduct business as an independent operating company, we look forward to the joint benefits of broader product, market, and customer opportunities."

Scott Newman, president of Voltronics, will remain to manage Voltronics as an independently operating company. Concerning the acquisition, Newman states, "It makes logical sense to create an alliance between a fixed and variable capacitor company. We have many common customers and can combine our sales organizations to achieve the best possible market penetration.

"Our manufacturing operation will remain in New Jersey, and all of our personnel, who, on average, have been with the company about 11 years, will continue on in their same positions."

Voltronics has been a family-run business since 1963. The company was founded by Scott Newman's father, Richard, in East Hanover, NJ. Scott Newman says, "My father had always said, if we were going to sell the company, Dover would be the one to sell it to." The acquisition process began about a year ago at the Microwave Theory & Techniques Symposium (MTT-S) in Philadelphia, PA, finally coming to contract on April 28th of this year, and closing on May 25th. Dover Technologies, with holdings that include Dow-Key Microwave, K & L Microwave, and Vectron, is part of the Dover Corp., a multibillion-dollar company that consists of more than 50 companies and is publicly traded on the New York Stock Exchange. MRF


INITIATE: SOLVE SEQUENCE
HFSS™
3D full-wave electromagnetic-field solver for component design and optimization
ANSOFT DESIGNER™
All-inclusive system, circuit and planar EM design environment for high-speed and high-frequency systems
NEXXIM™
The next state-of-the-art circuit simulator for high-capacity,high-performance designs
Q3D EXTRACTOR™
3D quasi-static field solver for RLCG parasitics and SPICE model extraction


SOLVE

## CONTRACTS

**TECOM Industries, Inc.**—Has been awarded a contract by Boeing for delivery of 15 INMARSAT T-4000 Aero-H High Gain Antennas (HGA) to meet FY '05 C-17 Secure Enroute Communications Program-Improved (SECOMP-I) program requirements. Boeing is the prime contractor to integrate the US Army's Secure Enroute Communications Package—Improved (SECOMP-I) into the C-17 Globemaster III aircraft. Follow-on awards are scheduled for FY '06 and FY '07 for 15 ship sets per year totaling $2 million.

**L-3 Communications ESSCO**—Announced that they have been awarded a major development contract by the Massachusetts Institute of Technology's Lincoln Library to design, fabricate, and install a series of sophisticated technology upgrades to the 37-meter-diameter Haystack Radio Telescope located in Westford, MA. The large-scale contract, to be executed over the next three years, will include design, fabrication, and field installation efforts.

**BAE Systems**—Has been awarded a $34.5 million contract from the Office of Naval Research to manufacture 132 high-frequency (HF) transmitters for installation in the High Frequency Active Auroral Research Program's (HAARP) phased-array antenna system.

The HAARP program collects and assesses data to advance knowledge of the physical and electrical properties of the Earth's ionosphere.

**REMEC, Inc.**—Has received an initial $9.9 million production contract from Raytheon Missile Systems for the TOW (Tube-Launched, Optically Tracked, Wire-Guided) missile second-generation upgrade program. This contract is a result of Raytheon's recent demonstrated success to prove feasibility to add expanded capability to the TOW weapon system. With the production option for additional microwave units, the total contract value has a potential of greater than $17 million for the first three production lots for REMEC. This program is the result of an earlier development success for the TOW Gen 1 system in which over 1000 production upgrade units were produced by REMEC for this missile configuration. The new TOW Gen 2 production contract includes delivery of 1501 Integrated Microwave Assemblies (IMAs), production rate tooling, and long lead material funding for an additional 807 IMAs. Delivery is scheduled to begin later this year with contract completion in 2006.

## FRESH STARTS

**RF Micro Devices, Inc.**—Announced that it has established an assembly facility at its Beijing, China location to provide internal module packaging capabilities.

The new assembly operation is expected to become fully operational in the December 2004 quarter.

**TEMEX**—Granted BFi OPTiLAS the representation and the distribution of some of its RF product lines. Both companies have a strong willingness to develop such products in the European market. Those main lines are SAW filters (short-range devices), waveguide and coaxial isolators/circulators, and PIN diodes.

**Microwave Circuits, Inc.**—Has decided to relocate its headquarters from Washington, DC to Lynchburg, VA. Through a $2.1 million investment, the company will create 200 new, high-paying jobs for Lynchburg. Located in the Kemper Building in downtown Lynchburg, Microwave Circuits will manufacture its new, patent-pending technology for use in homeland security and Department of Defense (DoD) applications.

**Hittite Microwave Corp.**—Announced the appointment of a new sales representative firm to serve customers in the Eastern Canada provinces of Ontario, Quebec, New Brunswick, Prince Edward Island, and Nova Scotia. Repwave, Inc., headquartered in Ottawa, Ontario, is a technical sales agency providing sales representation for industry-leading manufacturers of RF/microwave and optical components. Repwave's sales organization has over 30 years of professional sales experience covering wireless communications and optical networks.

Repwave can be contacted by phone at (613) 270-9811, via fax at (613) 270-9812, or e-mail at frank.masciotra1@sympatico.ca.

**BI Technologies**—Has added Weiss Co. to its list of authorized sales representatives. With more than 35 years of sales and service experience in Canada, Weiss Co. represents several complementary passive, electro mechanical, and active electronic product lines for a wide range of customer needs.

With sales offices in Montreal, Ottawa, Toronto, and Vancouver, Weiss Co. will represent BI's full line of electronic and magnetic components, including trimming and precision potentiometers, position sensors, turns counting dials, resistor networks, integrated passive networks, switches, transformers, inductors, hybrid microelectronics, and custom integration products.

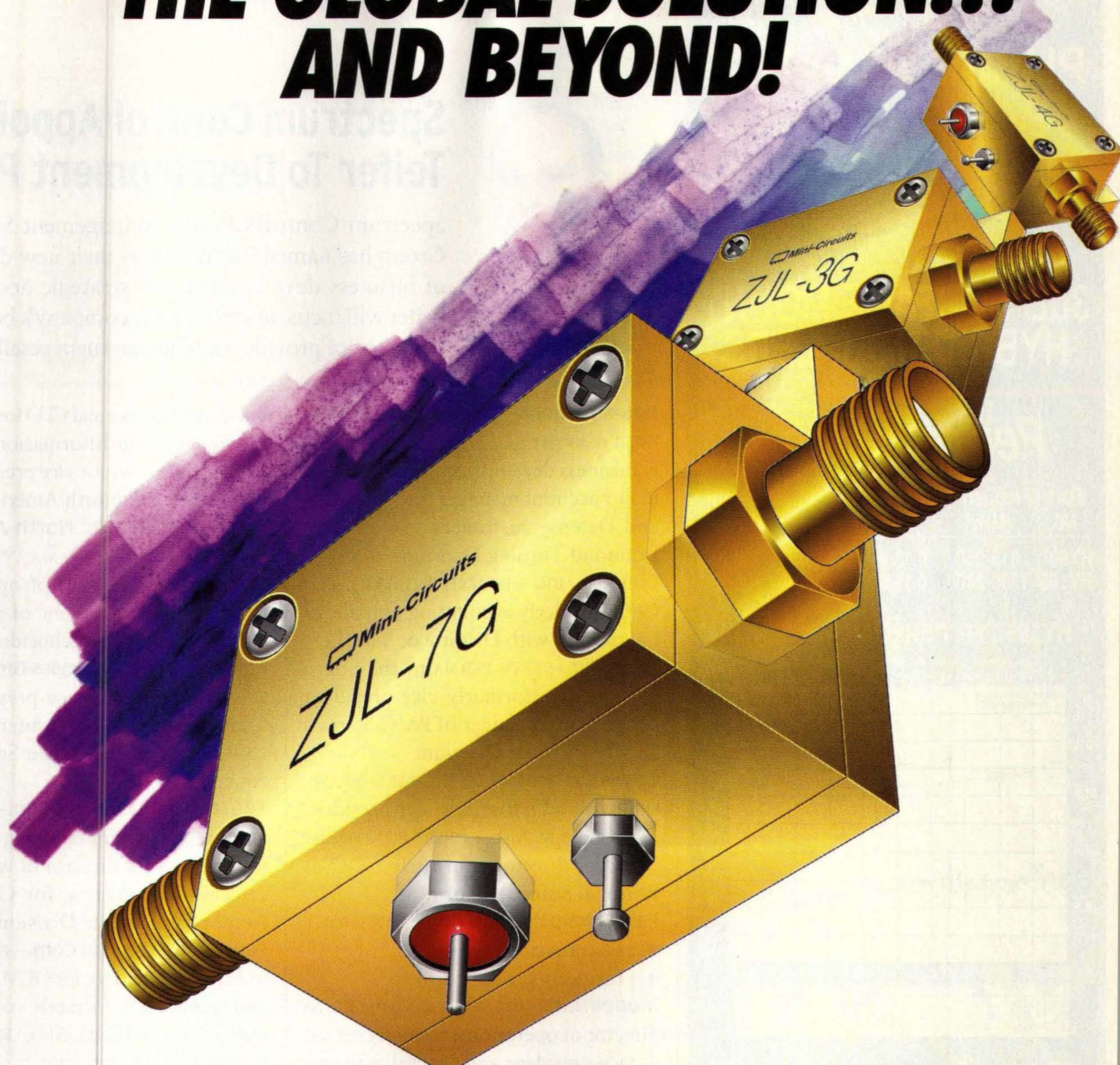
For more information on Weiss Co., see their website at www.weissco.ca.

**Elcoteq Network Corp.**—Announced that it has joined the WiMAX Forum. As a member of the WiMAX Forum, Elcoteq is dedicated to supporting its clients and the communications industry by manufacturing products and providing supporting services that adhere to the IEEE 802.16 standard.

**Applied Wave Research, Inc.**—Announced a corporate agreement with Ashvattha Semiconductor, Inc. for the company to purchase AWR's Analog Office design suite. Ashvattha will utilize the Analog Office software for the design of its RF integrated circuits (RF ICs), which integrate multiple standards on a single chip.

Ashvattha is a provider of highly integrated RF chips for wireless device manufacturers. MRF

# THE GLOBAL SOLUTION... AND BEYOND!




## 10MHz to 7GHz AMPLIFIERS from $99.95 (1-9 qty.)

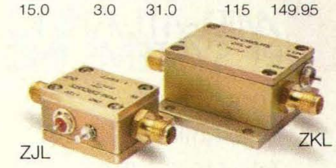
From amateur radio to cellular to satellite applications, with medium output power up to 17dBm, Mini-Circuits versatile ZJL and ZKL connectorized amplifiers offer the broad range of choices designers demand for achieving high system performance goals. Ultra-wideband models deliver **gain ranging from 9 to 40dB** and IP3 up to +32dBm. But beyond the performance and reliability built into these miniature 12V amplifiers lies another important feature, the low price...from only $99.95! Call now for fast delivery.

***Mini-Circuits...we're redefining what VALUE is all about!***

**SPECIFICATIONS**

| Model | Freq (MHz) | Gain (typ) Midband (dB) | Gain (typ) Flat (±dB) | Max. $P_{out}$[1] (dBm) | Dynamic Range (Typ @2GHz[2]) NF(dB) | Dynamic Range (Typ @2GHz[2]) IP3(dBm) | I(mA)[3] | Price $ea. (1-9) |
|---|---|---|---|---|---|---|---|---|
| ZJL-5G | 20-5000 | 9.0 | ±0.55 | 15.0 | 8.5 | 32.0 | 80 | 129.95 |
| ZJL-7G | 20-7000 | 10.0 | ±1.0 | 8.0 | 5.0 | 24.0 | 50 | 99.95 |
| ZJL-4G | 20-4000 | 12.4 | ±0.25 | 13.5 | 5.5 | 30.5 | 75 | 129.95 |
| ZJL-6G | 20-6000 | 13.0 | ±1.6 | 9.0 | 4.5 | 24.0 | 50 | 114.95 |
| ZJL-4HG | 20-4000 | 17.0 | ±1.5 | 15.0 | 4.5 | 30.5 | 75 | 129.95 |
| ZJL-3G | 20-3000 | 19.0 | ±2.2 | 8.0 | 3.8 | 22.0 | 45 | 114.95 |
| ZKL-2R7 | 10-2700 | 24.0 | ±0.7 | 13.0 | 5.0 | 30.0 | 120 | 149.95 |
| ZKL-2R5 | 10-2500 | 30.0 | ±1.5 | 15.0 | 5.0 | 31.0 | 120 | 149.95 |
| ZKL-2 | 10-2000 | 33.5 | ±1.0 | 15.0 | 4.0 | 31.0 | 120 | 149.95 |
| ZKL-1R5 | 10-1500 | 40.0 | ±1.2 | 15.0 | 3.0 | 31.0 | 115 | 149.95 |

NOTES:
1. Typical at 1dB compression.
2. ZKL dynamic range specified at 1GHz.
3. All units at 12V DC.




**Mini-Circuits®**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661 ***INTERNET*** http://www.minicircuits.com

For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE • EEM • MICROWAVE PRODUCT DATA DIRECTORY • WWW.RFGLOBALNET.COM

***ISO 9001** CERTIFIED*

F 232 Rev D


TEIFER

# Spectrum Control Appoints Teifer To Development Post

Spectrum Control's Power Management Systems Group has named JOE TEIFER as their new director of business development and strategic accounts. Teifer will focus on growing the company's business with service providers and government resellers.

**Janos Technology, Inc.**—ROBERT WINKLER to system sales engineer; formerly business development specialist and major account manager for Aerospace and Defense customers at Corning's Diamond Turning Division.

**Cimetrix, Inc.**—DENNIS P. GAUGHER to CFO; formerly accounting and auditing partner with Deloitte & Touche.

**TeraChip**—STEVE PERNA to the board of directors; formerly vice president and general manager of PMC-Sierra's Service Provider Division.

**Clarus Systems, Inc.**—RICHARD WHITEHEAD to CTO; formerly vice president of technology. Also, ROBERT BOND to the board of directors; formerly COO at Rational Software Corp.

**Park Electrochemical Corp.**—ANTHONY W. DIGAUDIO to vice president of quality; formerly product director.

**Modelithics, Inc.**—DICK WHISLER to director of operations; formerly served as vice president and general manager for several electronic-instrumentation and electronic-component companies.

**IMS Connector Systems GmbH**—GÜNTER MÖBIUS to managing director; formerly member of the executive board of Sauter AG.

**Stretch, Inc.**—REYNETTE AU to vice president of marketing; formerly president and CEO for Triscend Corp.

**Intellon Corp.**—ANDREAS MELDER to senior vice president of sales, marketing, and business development; formerly COO at Clarisay, Inc.

**National Security Telecommunications Advisory Committee (NSTAC)**—PATRICIA RUSSO to the role of vice chairman; continues as chairman and CEO of Lucent Technologies.

**Raytheon Co.**—NANCY H. GREER to vice president of finance and CFO for Raytheon Intelligence and Information Systems (IIS); formerly senior vice president and CFO at Alcatel North America.

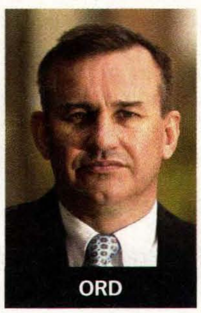
**Schneider Electric North American Operating Division**—MARY FRANCES COX to vice president of operations; formerly vice president of manufacturing operations at Schneider Electric.

**Powerhouse Technologies Group, Inc.**—DAVID R. WELLS to vice president for finance operations; formerly acting COO/CFO at Insurance Services of America.

**TECOM Industries, Inc.**—MAGDY MICHAEL to senior marketing manager; formerly senior director of worldwide sales and marketing for California Amplifier's Satellite Division.

**Park Electrochemical Corp.**—EDDIE MOK to Asia Pacific director for OEM marketing and technology; formerly country service manager in China. Also, LEENA GULIA to senior OEM marketing engineer; formerly OEM marketing engineer.

**CSR plc**—RICHARD ORD to vice president of the Bluetooth Business Unit; formerly vice president at VLSI Technology and Philips Semiconductor.


ORD


DEVINE

**Indium Corp.**—LEO M. DEVINE to marketing development manager for Wave Solder Products; formerly marketing communications manager. MRF

## ▸SHORT COURSES

**CMOS Analog Integrated Circuits**
August 2-6 (Atlanta, GA)
For further information, contact:
Georgia Institute of Technology
Professional Education—R
P.O. Box 93686
Atlanta, GA 30377-0686
(404) 385-3500, FAX: (404) 894-8925
Internet: www.pe.gatech.edu — KEYWORD: CMOS

**R.A. Wood Short Courses**
*RF Power Amplifiers, Classes A-S: How the Circuits Operate, How To Design Them, & When To Use Each*
September 20-21 (Syracuse, NY)
November 8-9 (Philadelphia, PA)
*Wireless Engineering—For Designers*
September 13-17 (Syracuse, NY)
November 15-19 (Philadelphia, PA)
*Introductory RF and Microwaves*
September 20-21 (Syracuse, NY)
November 8-9 (Philadelphia, PA)
*RF and Microwave Receiver Design*
September 22-24 (Syracuse, NY)
November 10-12 (Philadelphia, PA)
For further information, see:
www.rawood.com/seminars
For a PDF course brochure, see:
www.rawood.com/ftp_files/course_brochure_2003-3.pdf

**Streamlining the Product Development Process**
November 8-9 (Pasadena, CA)
California Institute of Technology
(626) 395-4045, FAX: (626) 795-7174
e-mail: execedu@caltech.edu
Internet: www.irc.caltech.edu

## ▸MEETINGS

**Portable Power Conference & Expo**
September 12-14 (San Francisco, CA)
The Argent Hotel
Hosted by IDG World Expo
For further information, contact:
Jennifer LaFond
(508) 424-4809
e-mail: jennifer_lafond@idg.com
Internet:
www.portablepowerconference.com

**37th Annual IICIT Connector & Interconnection Technology Symposium & Trade Show**
September 13-15 (Dearborn, MI)
Hyatt Regency Dearborn
Internet: www.iicit.org

**CST European User Group Meeting**
September 23-24 (Darmstadt, Germany)
For further information, contact:
Ruth Jackson, Marketing Communications
+49 (0)6151 7303-0, FAX: +49 (0)6151 7303-10
e-mail: info@cst.com
Internet: www.cst.com

**WNCG Wireless Networking Symposium 2004**
October 20-22 (Austin, TX)
Omni Austin Hotel Downtown
Register online at:
https://lifelong.engr.utexas.edu/wncg/checkout.cfm?course_num=827&course_type=short
For sponsorship or speaking opportunities, contact Katherine White at (512) 471-2602
e-mail: kmwhite@mail.utexas.edu
Internet: www.wncg.org

**10th Annual Manufacturing in Mexico Summit**
October 21-24 (San Carlos, Sonora, Mexico)
Hotel San Carlos
For more information, contact:
(520) 889-0022 ext. 164
Internet: www.offshoregroup.com

**ASTM Committee B02 on Nonferrous Metals and Alloys**
November 8-10 (Washington, DC)
For further information, contact Jeffrey Adkins, ASTM — (610) 832-9738
e-mail: jadkins@astm.org
Internet: www.astm.org/COMMIT/B02.htm

**electronica 2004**
November 9-12 (Munich, Germany)
New Munich Trade Fair Centre
Randi M. West, (312) 377-2650
Internet: www.munichtradefairs.com

**ASTM Committee B10 on Reactive and Refractory Metals and Alloys**
November 10-11 (Washington, DC)
For further information, contact Jeffrey Adkins, ASTM — (610) 832-9738
e-mail: jadkins@astm.org
Internet: www.astm.org/COMMIT/B10.htm

**2004 IEEE International Electron Devices Meeting**
December 12-15 (San Francisco, CA)
The Hilton San Francisco
(301) 527-0900 ext. 103, FAX: (301) 527-0994
e-mail: iedm@his.com
Internet: www.ieee.org/conference/iedm

## ▸CALL FOR PAPERS

**2005 International CES**
January 6-9, 2005 (Las Vegas, NV)
Speaker proposals are due by July 30
Proposed presenters will be notified of acceptance by September 24
Proposals can be submitted online at www.CESweb.org/speakers

**IEEE International Solid-State Circuits Conference**
February 6-10, 2005 (San Francisco, CA)
San Francisco Marriot Hotel
2005 Conference Theme: "Entering the Nano-Electronic Integrated-Circuit Era"
Abstract must not exceed 325 characters
Abstract submission deadline: September 20
Notification of acceptance: October 22
e-mail: ISSCC05@courtestassoc.com
Internet: www.isscc.org/isscc

## Studying Cellular-Telephone Emissions On The Head

CELLULAR-TELEPHONE EMISSIONS have been studied extensively according to specific-absorption-rate (SAR) models of the human head. To take these studies one step further, Hsing-Yi Chen and Han-Peng Yang of the Department of Communications Engineering of Yuan Ze University (Taoyuan-shian, Taiwan) have examined the local maximum SAR induced in spherical, cubical, coarse, and realistic human-head models exposed to a cellular telephone using the finite-difference time-domain (FDTD) method of analysis at 900 and 1800 MHz. The authors note that for bioelectromagnetic applications, the FDTD method has been found to be extremely versatile and has been used for whole-body and partial-body studies due to spatial uniform or nonuniform electromagnetic (EM) fields.

In their modeling of the human head, special attention was paid to the dielectric constant and conductivity of the head, the cellular telephone, and the excitation of the antenna. The researchers based their studies on the effects of different human head shapes and the influence on SAR. In one of their models, for example, the had wraps around three sides of the cellular telephone and consists of a core of bone surrounded by a layer of muscle. The equivalent dielectric constant, conductivity, and mass density are determined by assuming different volume fractions for the bone and muscle at 900 and 1800 MHz. The researchers found that, while the shape of the human head model played a minor role in the final SAR, the homogenous human head models led to higher SAR values than nonhomogenous human head models. Other factors to be considered were the positioning of the antenna and the relative distance from the telephone to the head. See "SAR Affected by Shapes and Electrical Properties of the Human Head Exposed to a Cellular Telephone," *Microwave and Optical Technology Letters,* July 5, 2004, Vol. 42, No. 1, p. 1.

## Novel Discone Antenna Serves UWB Systems

DISCONE ANTENNAS ARE OFTEN USED to monitor wide frequency bands. This type of antenna generally has a low-cutoff/high-cutoff bandwidth ratio of 1/8 for the UHF band. The critcal matching factor for broad bandwidth is the gap height between the antenna disk and the cone skirt. Researchers Jinu Kim and Seong-Ook Park of the School of Engineering, Information and Communications University (Daejeon, Korea) explored the design and optimization of a double-discone antenna configuration for ultrawideband (UWB) communications applications. The double-discone antenna combines the traits of a conventional large discone antenna with bandwidth of 300 MHz to 2.4 GHz and a smaller design with bandwidth from 2.4 to 9.0 GHz.

Using finite-element-method (FEM) analysis tools to design the antenna, and a commercial vector network analyzer (model 8510C) from Agilent Technologies (Santa Rosa, CA) to perform measurements on a prototype design, the researchers developed an antenna with 30:1 bandwdith from 282 MHz to 8.93 GHz. The antenna VSWR over that wide range was a respectible 2.0:1 or less (very close to simulated values). The antenna was found to provide even radiation patterns as wide as 100 to 140 deg. The measured gain was found to peak at 7 dBi at 4 GHz, and exceed 5 dBi for most of the covered bandwidth, with simulated gain closely approaching the measurement values within an accuracy of better than 1 dB. See "Novel Ultra-Wideband Discone Antenna," *Microwave and Optical Technology Letters,* July 20, 2004, Vol. 42, No. 2, p. 113.

## Patch Antenna Fits WLAN Access Points

WIDE ANTENNA RADIATION PATTERNS CHARACTERIZING high-speed, are needed for wireless-local-area-network (WLAN) access points. Often monopole or dipole antennas are used for this purpose, with good omnidirectional patterns. But Saou-Wen Su and fellow researchers from the Department of Electrical Engineering at the National Sun Yat-Sen University (Kaohsiung, Taiwan) discovered that a properly designed patch antenna can also provide a wide horizontal radiation pattern that is well suited for WLAN access points.

The patch antenna consists of an inverted-L narrow radiating patch and an inverted-V ground plane. The compact design provides a 3-dB beamwidth of 40 deg. in the E-plane at 2442 MHz and 150 deg. in the H-plane at the same frequency. The on-axis gain for both beamwidths is 3.7 dBi. The 2.4-GHz antenna is about one-half the size of a conventional patch antenna. See "A Patch Antenna with a Wide Horizontal Radiation Pattern for WLAN Access Point," *Microwave and Optical Technology Letters,* July 20, 2004, Vol. 42, No. 2, p. 161.

DESIGN

# ESD-Hardened Device Fuels UHF Amplifiers

## This rugged bipolar transistor has been designed to withstand high levels of ESD making it well suited for UHF automotive electronics applications.

**Automotive applications in the ultra-high-frequency (UHF) band require transistors that provide good RF performance but are also robust. The BFP460 from Infineon Technologies (Munich, Germany) is a general-purpose transistor that is electrostatic-discharge (ESD)-hardened for such applications. It benefits from a silicon-bipolar process technology with 23-GHz transition frequency and can safely withstand** ESD pulses of 1500 W between any pair of terminals. The effectiveness of the new device will be demonstrated in a UHF low-noise amplifier (LNA) that is ideal for automotive use.

**JAKOB HUBER**
**Title**
Infineon Technologies AG, Rosenheimer Strausse 116, 81669 Munich, Germany; (49) 89-234-0, FAX: (49) 89-234-2-46-94, Internet: www.infineon.com.

**GERARD WEVERS**
**Title**
Infineon Technologies N.A. Corp., 1730 North First St., San Jose, CA 95112; (408) 501-6000, FAX: (408) 501-2424, e-mail: gwevers@infineon.com, Internet: www.infineon.com.

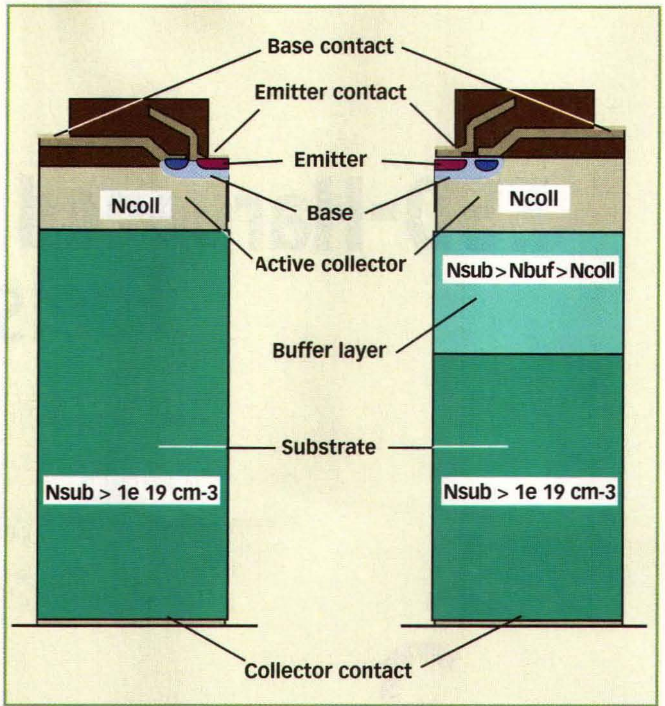
A variety of automotive systems now make use of RF technology, including remote-keyless entry (RKE), Global Positioning System (GPS), Satellite Digital Audio Radio Services (SDARS), and tire-pressure monitoring systems (TPMS). Each of these systems require RF building blocks having good performance, low cost, and high levels of ruggedness/robustness **(Table 1)**.

As RF devices have scaled to smaller dimensions for higher-frequency use, they tend to exhibit higher current densities (approximately 3 mA/µm2 or 300,000 A/cm2 at a typical transistor operating point) while the breakdown voltage has dropped (from typically 50 V to around 3 V). The breakdown volt-

**Table 1: A sampling of RF systems for automotive applications**

| FREQUENCY RANGE | DESCRIPTION | COMMENTS |
|---|---|---|
| 315 MHz (NAFTA)<br>434 MHz (Europe) | Remote keyless entry (RKE)<br>Tire-pressure monitoring systems (TPMS) | TPMS in US, RKE worldwide |
| 1.575 GHz | Global Positioning System (GPS) | Location/navigation |
| 2.400 to 2.483 MHz | Bluetooth, radio-frequency identification (RFID) toll tags | e.g., Bluetooth headset for cellular phone "hands free," toll collection |
| 5.850 to 5.925 GHz | Dedicated short-range communications ("DSRC") in NAFTA | Safety (e.g., over-height truck warning, railway—roadway warning, etc.), toll collection, weather and road info, etc. |
| 23.9 to 24.7 GHz | Automotive radar | Safety—e.g., collision avoid ance, adaptive cruise control |




**1. The addition of a medium-doped buffer layer (right) to a conventional bipolar transistor design (left) improves the device ruggedness with respect to ESD pulses.**

age as well as the optimum current density is determined by the thickness and the doping of the collector. For a high transition frequency, the collector must be kept thin. For high gain, all internal parasitic capacitances must be kept small, which is a driving factor for shrinking lateral dimensions, but also makes a transistor more sensitive to ESD damage.

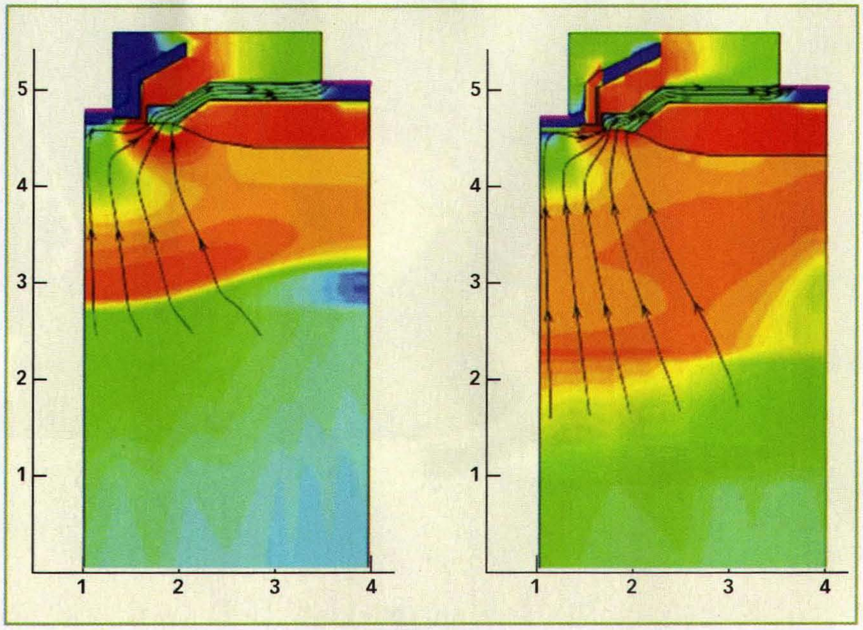
Rigorous study of transistor ESD failure mechanisms have shown that there is room for improvement in device ESD robustness. The discrete BFP460 transistor incorporates some of the findings of such research to withstand 1500-V human-body-model (HBM) pulses while achieving a cutoff frequency of 23 GHz, maximum stable gain of 17.5 dB and minimum noise figure of 1.1 dB at 1.8 GHz.

The most widely used standard for ESD testing is the HBM detailed in MIL STD 883D. In this standard, a 100-pF capacitor is charged to a reference voltage ($V_{REF}$). The reference voltage power

**Table 2: Summarizing BFP460 feedback LNA performance**

| PARAMETER | RESULT | COMMENTS |
|---|---|---|
| Frequency range | <300 MHz to > 1 GHz | 315-, 345-, 390-, 434-, and 900-MHz ISM bands covered |
| DC current consumption | 4.5 mA typical | |
| Supply voltage | 5.0 V | Can be used down to 2.5 V |
| Gain | 15. 9 dB at 315 MHz<br>15.5 dB at 434 MHz<br>13.5 dB at 900 MHz | |
| Noise figure | 1.4 dB at 315 MHz<br>1.4 dB at 434 MHz<br>1.6 dB at 900 MHz | |
| Input power (1-dB comp.) | –21 dBm at 315 MHz | |
| Input third-order intercept | –11.4 dBm at 315 MHz | |
| Input return loss | 11.8 dB at 315 MHz<br>11.5 dB at 434 MHz<br>10.3 dB at 900 MHz | Good broadband match |
| Output return loss | 18.1 dB at 315 MHz<br>16.9 dB at 434 MHz<br>13.6 dB at 900 MHz | Good broadband match |
| Reverse isolation | 21.4 dB at 315 MHz<br>21.3 dB at 434 MHz<br>20.5 dB at 900 MHz | |


DEFENSE LINE
Mission Accomplished
HUBER+SUHNER products for Space and Defense applications – your system will accomplish the mission.
HUBER+SUHNER's product line features outstanding performance characteristics.
■ NEMP and lightning protection for manpack, vehicle and land based communications
■ Rugged semi-rigid RF cables and assemblies
■ SUCOFLEX: high performance cable series up to 60 GHz
■ Reliable delay lines
HUBER+SUHNER
USA and Canada:
Toll free 1 866 HUBER SUHNER
(1-866-482-3778)
Fax 1-847-397-2882
www.hubersuhnerinc.com
HUBER+SUHNER AG
Mobile Communications+Electronics
9100 Herisau, Switzerland
Phone +41 (0)71 353 41 11
Fax +41 (0)71 353 45 90
www.hubersuhner.com
HUBER+SUHNER – Excellence in Connectivity Solutions




**2. This comparison of field distributions for an ESD pulse shows the even current distribution for the device with the buffer layer (right) compared to a conventional device without buffer layer (left).**

supply is then disconnected, and the capacitor is discharged while connected through a series 1500-Ω resistor to the device under test (DUT). Reference voltages as low as 100 V are used for low-noise transistors with small device geometries and higher sensitivity to ESD, while voltages to 5000 V are used for older, lower-performance, larger-geometry transistors **(Tables 1 and 2 in ref. 4)**. A DUT is considered "rated" for a particular ESD level when it shows no degradation or failure when subjected to such tests at that level of $V_{REF}$. Typically, such tests have been performed on packaged devices, although ESD testing is now also performed at the on-wafer chip level.

An ESD pulse can best be understood as a rapid surge of current within the device. For a first-order approximation, it is valid to assume that this event occurs too quickly to permit heat to spread or dissipate within the device experiencing this current surge. As a result, the temperature increase resulting from the ESD induced current surge *is proportional to the square of the current density*, and there exists a limit current density level beyond which actual localized melting of the device's silicon occurs. It is in fact this melting of the silicon material which leads to device failure. As *current density* is the key item leading to device failure, transistors with a large emitter periphery or large area are more rugged than smaller ones. Contrary to common belief, there is little correlation between a transistor's collector-emitter breakdown voltage ($V_{CEO}$) and its resistance to ESD damage.

For improved robustness, designers of RF integrated circuits (RF ICs) have developed internal ESD protection structures which help shield the ESD-sensitive RF input and output terminals from harmful ESD events.[1,2] Unfortunately, these ESD-protection structures also "load" the RF terminals with stray capacitance, inductance, and losses, thereby causing degradation in performance and making such structures unsuitable for use with discrete devices (where higher performance is expected).

In a three-terminal device like a bipolar transistor, there are six possible ways to apply an ESD pulse across any two of the device's terminals, while the unused device terminal remains "open" (not connected). Usually, the transistor is most susceptible to damage when ESD pulses are applied across the positive-negative (PN) junctions in a reverse

Mini-Circuits
MCA1

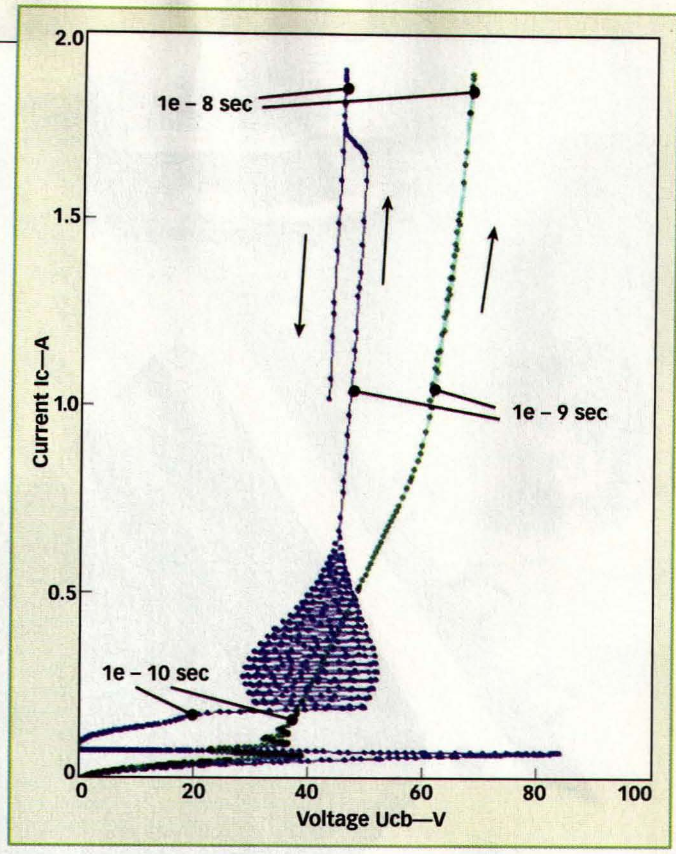
direction–e.g., with the polarity that causes a reverse-bias condition at a given junction. While dependent on specific semiconductor process technology, the collector-base junction is usually the weak link in an RF transistor. If the ESD-induced current surge is high enough, all three regions of the bipolar transistor are flooded with free carriers (electrons in the case of an NPN transistor).

During an ESD event, the base-collector space-charge is driven down into the highly doped substrate or (buried layer in RF ICs).[1] Nearly all of the transistor's voltage drops over the collector-substrate boundary, yielding increased field strength in this region (the density of free electrons in the collector region has surpassed the doping density). Since the free electron charge in the collector must be compensated by a counter charge, the only region where it can be built up is in the highly doped substrate (or buried layer).[2] If this field reaches the internal breakdown field strength of approximately $3 \times 10^5$ V/cm in the case of silicon, massive impact ionization occurs. More free carriers are generated (electrons and holes) and a runaway process takes place, with external voltage breakdown. This effect is called "second snapback" in ref. 1, after the $V_{CEO}$ snapback effect.

Most of the energy contained in the ESD pulse is released at the site of the highest field strength which increases the local device temperature. This in turn increases the number of free carriers due to the intrinsic conductivity mechanism. The process continues its downward spiral via a positive feedback mechanism and as a consequence the current tends to focus onto an ever smaller spot with subsequent melting and burnout of silicon material.

To some extent, the addition of a distributed series resistance to the current path can help avoid the concentration of ESD-induced surge current.[3]

The series resistance forces an even distribution of surge current, and helps avoid the subsequent destructive mechanism. Careful design of a transistor cell can also help avoid such destructive effects. For example, any crystal defect, any sharp edge, any abrupt corner may cause a resulting increase in localized electric field strength; such defects should be avoided.



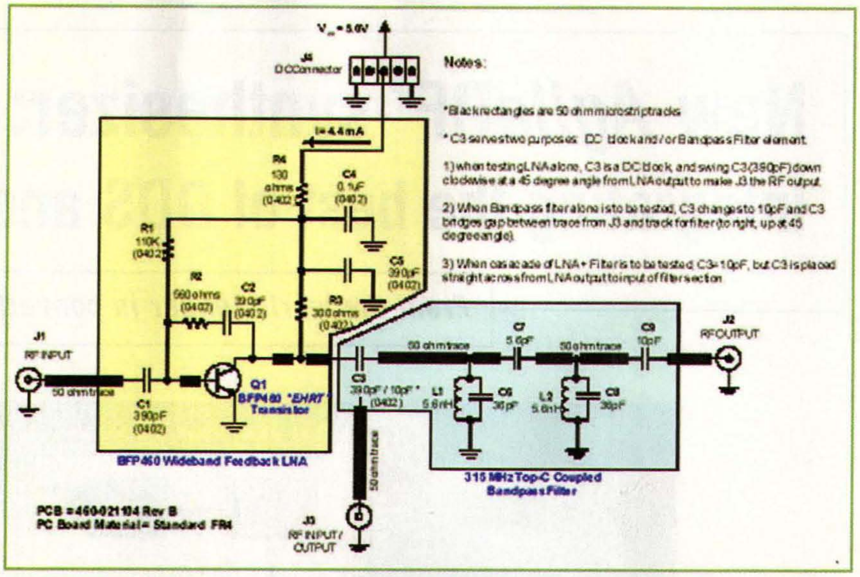

**3. These simulated I-V curves compare a conventional transistor design (blue) with an improved design (green). The simulation assumed a capacitor charges to 3000 V and discharged.**

A straightforward way to reduce ESD-induced fields is by choosing a lower doping density in the substrate in order to distribute counter charges more deeply into the substrate. Unfortunately, this approach affects the substrate resistance (and RF performance). A better way is to insert a buffer layer between the substrate and the active collector region.[5] The dopant concentration of this buffer region must be higher than the active collector region, but lower than that of the substrate; still, it must be high enough for the buffer to serve as a substrate under normal operation **(Fig. 1)**. This design approach was employed in the BFP460 to boost ESD tolerance from 300 to 1500 V (for a packaged device with 64-µm$^2$ emitter area).

## Simulating Performance

The DESSIS CAE simulator was used to learn more about ESD mechanisms. The process simulator DIOS was applied to two configurations (with and without a buffer layer) of a basic RF transistor cell as a first analysis step. For the ESD simulation, a HBM circuit was constructed around the physical model, and the capacitor discharge was calculated in the time domain. Since the base-collector path under reverse pulse load was found to be the weakest path, it was used in the analysis. The reference capacitor was loaded to 3000 V with peak current density of about 12.6 mA/µm$^2$ **(Fig. 2)**. In the conventional transistor, a zone of extremely high field is generated at the collector–substrate boundary while the field remains much lower in the improved design as a result of the buffer zone. This is due to the fact that the compensating charge for the free electrons of the ESD current is distributed more deeply. A high-strength electric field is also generated around the inner base contact since this is the site of highest current density. Experimental analysis of failed devices in most cases showed melting of silicon at this location.

The current-voltage (I-V) curves of **Fig. 3** display the action of the buffer layer. The curves are based on several time steps, with arrows and marks indicating the time flow. The oscillations at the beginning are caused by subsequent ignition of avalanche and voltage breakdown due to the generated free carriers but play




**4. This schematic diagram shows the feedback LNA based on the BFP460, along with the optional bandpass filter at right.**

no role in the ESD analysis. The device with the buffer layer has an I-V characterisitic with positive slope: if the avalanche should "burn" hotter at one spot, a higher voltage would be required for it. Since the voltage is fixed and the same for any spot, however, current crowding is prohibited.

The transfer of production of all discrete RF transistors into Infineon's new self-aligned double poly process also offered the opportunity to produce the new BFP460 design. In this new process, the emitter is formed by depositing an n-poly layer, rather than by implanting arsenic dopant for the emitter in the older processes. The new approach provides tighter control of production process parameters and supports high-volume runs of transistors within narrow ranges of parameter distributions. For example, DC current gain ($h_{FE}$) of planar RF transistors, which tends to normally scatter over a wide range, can be controlled within a narrow window of 100 to 150 with high yields in BFP460 production.

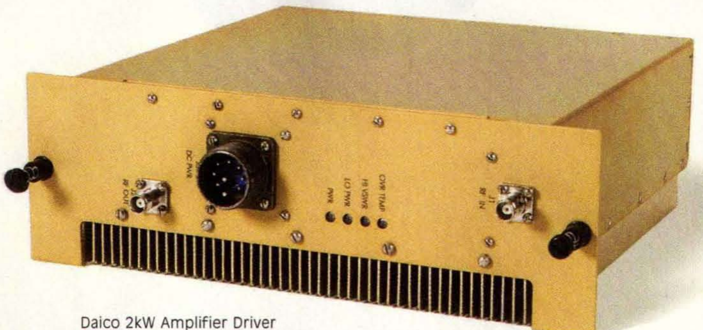
The BFP460 was used in a wideband feedback LNA for UHF **(Fig. 4)**, although the ESD-hardened transistor is suitable for a wide range of applications. This particular LNA was used to boost the sensitivity and range of receiver RF ICs for RKE and TPMS applications at 315 and 434 MHz. The LNA requires only nine components, including the BFP460 transistor. For reduced cost, no chip coils (inductors) are used, just resistors and capacitors. The application board includes an optional low-cost, lumped-element bandpass filter set to a center frequency of 315 MHz. The filter may be retuned for 434 MHz, and is intended to reduce the effect of out-of-band "blocking" signals on the RKE receiver chain. The application board allows testing of the LNA by itself, the filter by itself, or the cascade of the LNA and filter together.

The LNA is designed for unconditional stability and exhibits good return loss, gain, and noise figure from 300 to 1000 MHz. It can be used at the 315-, 434-, or 900-MHz ISM bands with no changes required (Table 2). Interested readers should contact the author or this magazine for a copy of the Bill of Materials (BOM) for the LNA. Application boards based on the BFP460 are available from Infineon. MRF


**REFERENCES**

1. M. Streibl *et al.*, "Harnessing the Base-Pushout Effect for ESD Protection in Bipolar and BICMOS Technologies," *Microelectronics Reliability*, July 2003, Vol. 43, No. 7, pp. 1001-1010.
2. G. Bertrand *et al.*, "Analysis and compact modelling of a vertical grounded base bipolar transistor used as ESD protection in a smart power technology," *IEEE Journal of Solid-State Circuits*, Vol. 36, No. 9, September 2001.
3. J. Huber and E. Pettenpaul, United States Patent No. 5047355.
4. B. Ronan *et al.*, "High Current Transmission Line Pulse (TLP) And ESD Characterization of A Silicon Germanium Heterojunction Bipolar Transistor With Carbon Incorporation," *IEEE 40th Annual International Reliability Physics Symposium*, Dallas, TX, pp. 175–183.
5. Diefenbeck, Herzum, Huber, Müller, German Patent WO 0205732.

# OK, WE ADMIT IT... WE'RE INTO MUSCLE AMPLIFIERS



Daico 2kW Amplifier Driver
with 55 dB gain (combined)

## Our custom High-Power Amplifiers outperform the competition's right from the bench.

We've taken the lead again! Daico Industries is lifting amplifier stats higher in a new high-effiency, high-gain amplifier that's hard to beat.

Our amplifiers provide a new standard in power, efficiency and reliablility in the L-Band range. And this 2kW design with an output of +63.3 dBm provides extra advantages and features others can't, all in one package. Like uniform thermal performance for large and short pulse, thermal sharing between transistors, controls for monitoring power output, reverse power and temperature, and excellent flatness across bandwith. Plus, they're fully protected for VSWR mismatch all phases. What's more, our unique modular design supports manufacturablility, repeatability and serviceability developed and refined over more than 35 years in the IF/RF/microwave field.

That's why we can offer, "More power to your radar systems designers!" by simply calling: 310 507 5670.

**ELECTRICAL SPECIFICATIONS**

| Parameter | Min | Typ | Max | Unit | Notes |
|---|---|---|---|---|---|
| Frequency | 1.2 | | 1.4 | GHz | |
| Small Signal Gain | 53 | 55 | 58 | dB | |
| VSWR In/Out | | | 1:2/1 | | In 50 ohm |
| RF Out, P1DB Comp. | | +63 | 63.3 | dBm | |
| Harmonics Out II, III | 50 | 55 | | dBc | |
| Gain Tracking | -0.3 | 0.2 | +0.3 | dB | Unit-to-unit |
| Phase Tracking between amplifiers | -1.0 | ±-0.5 | +1.0 | degree | Unit-to-unit |
| VSWR Withstand Under Full Power | | | ∞:1 | | All phases |
| Efficiency | | 30 | | | |
| Duty | | | 10 | % | |
| Pulse Width | 0.001 | | 1.0 | Msec | |
| Pulse Droop | 0.0 | 0.02 | 0.1 | db | |

DAICO Industries

DAICO Industries, Inc.
1070 East 233rd Street
Carson, California 90745
Phone: 310 507 3242
Fax: 310 507 5701
www.daico.com

# Applying S-Parameters To Amplifier Design

This opening installment of an eight-part design series explains the concept of S-parameters and how they can be used to create basic transistor bias circuitry.

**JOSEPH F. WHITE**
**President**
JFW Technology, Inc., e-mail: jfwhite@ieee.org.

**Transistor amplifier designers rely on numbers to match active devices to surrounding circuitry and to each other. They may select a transistor from a catalog, but the circuit designer has no influence over the transistor's parameters. These are set by the device's geometry, the quality of the manufacturing process, and semiconductor physics. As a result, the circuit designer must be guided by a device's** measured scattering parameters (S-parameters) to determine the circuit-element values needed to surround an active device or devices in an amplifier design. This first installment of an eight-part design series will explore S-parameters; the series itself will transform any reader into a full-fledged amplifier designer.

To the circuit designer the transistor is a two-port network described by a table of S-parameters that have been measured over the frequency domain for which it has gain. After the bias and heat sinking needs of the transistor have been satisfied, the RF design proceeds using these S-parameters. At this point it is of no consequence whether the device is a bipolar transistor, a field-effect transistor (FET), or any other device whose S-parameters indicate the prospect of gain.

S-parameters are based upon the concept of *incident* ($a_i$) and *exiting* ($b_i$) waves. Customarily the $b_i$ waves are called *reflected* waves, but "exiting" is a better term since portions of the bi waves actually may result from energy that passes through rather than is reflected from the network. By using a and b waves, a linear network can be characterized by a set of simultaneous equations describing the exiting waves from each port in terms of the incident waves at all of the ports. The constants that characterize the network under these conditions are called S parameters.

For example, for a two-port network, the b wave leaving Port 1 ($b_1$) is the phasor sum of a wave reflected from the input port ($S_{11}a_1$) plus a wave that passed through the two-port from Port 2 ($S_{12}a_2$). That is,

$$b_1 = S_{11}\,a_1 + S_{12}\,a_2 \qquad (1)$$

and

$$b_2 = S_{21}\,a_1 + S_{22}\,a_2 \qquad (2)$$

where:

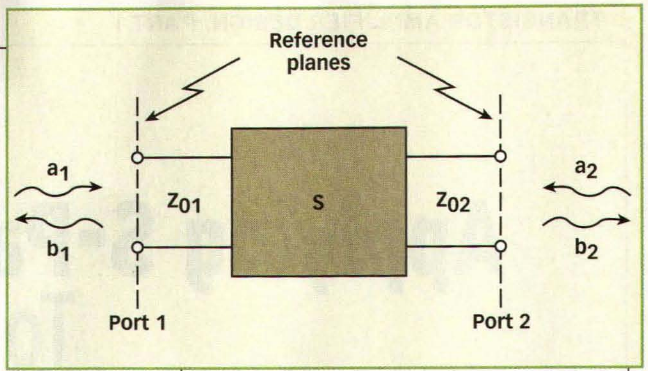
$$a_i = {}^{V_{iI}}\!\Big/\!\sqrt{Z_{0i}} = I_{iI}\sqrt{Z_{0i}} \qquad (3)$$

$$b_i = {}^{V_{iR}}\!\Big/\!\sqrt{Z_{0i}} = I_{iR}\sqrt{Z_{0i}} \qquad (4)$$

and the voltage at port 1, for example, is the sum of an incident voltage and a reflected voltage ($V_1 = V_{1I} + V_{1R}$). Similarly, the current at port 1 is the sum of an incident current and a reflected cur-

rent ($I_1 = I_{1I} + I_{1R}$). The normalized incident ($a_i$) and reflected ($b_i$) waves can be measured with the aid of directional couplers with matched source and loads presented to the two-port terminals. This is equivalent to the measurement provided by a network analyzer.

This measurement simplicity underlies the advantage of the *S* parameters, but it introduces a complication. Whereas the alternate Z, Y, and ABCD




**1. S-parameters derive from these defining conventions for incident (a) and reflected (b) waves.**

parameters depend only upon the network being measured, the *S-parameter values depend both upon the network and the characteristic impedances of the source and load used to measure it.* More about the consequences of this condition will be presented later in this article series.

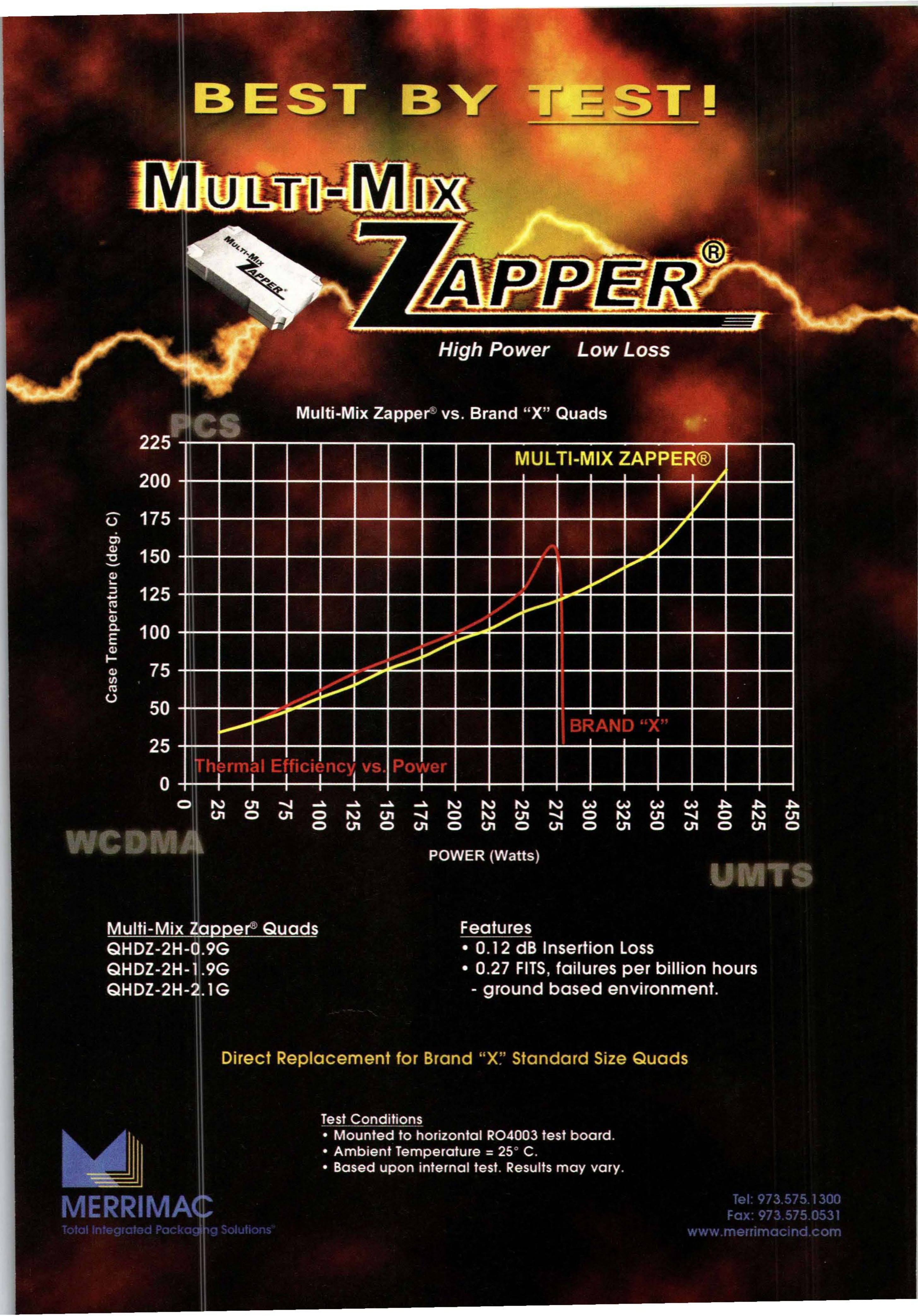
When the source and load impedances are the same as those used to determine the S-parameters, the magnitude of $S_{21}$ is the ratio of the outgoing wave, $b_2$, to the incoming wave, $a_1$. Hence, it is equivalent to the voltage or current gain of the amplifier. Similarly, the magnitude of the square of $S_{21}$ is equal to the power gain.

As an example, suppose we wish to design an amplifier to operate at 1 GHz with 50-Ω source and load impedances. On reviewing tables of S-parameters provided in a catalog or in an electronic file within a circuit simulator, suppose that the Motorola 2N6679A bipolar transistor is selected for the amplifier design. The **table** shows its S-parameters in standard format.

The magnitude of $S_{21}$ can be seen as 6.6 at 1 GHz. The basic gain, without tuning, in a 50-Ω system is:

$$G = 20 \log |S_{21}| = 20 \log 6.6 = 16.4 \text{ dB} \quad (5)$$

At this point, if this is considered satisfactory gain, it is simply a matter of designing a bias circuit.[2] For bias, a 20-V source should be used, since the S-parameter file indicates the performance was obtained with a 15-V bias between collector and emitter. From the transistor data, it can be seen that the performance was obtained with



BEST BY TEST!
MULTI-MIX ZAPPER®
High Power Low Loss
Multi-Mix Zapper® vs. Brand "X" Quads
PCS
WCDMA
UMTS
MULTI-MIX ZAPPER®
BRAND "X"
Thermal Efficiency vs. Power
Case Temperature (deg. C)
0 25 50 75 100 125 150 175 200 225
0 25 50 75 100 125 150 175 200 225 250 275 300 325 350 375 400 425 450
POWER (Watts)
Multi-Mix Zapper® Quads
QHDZ-2H-0.9G
QHDZ-2H-1.9G
QHDZ-2H-2.1G
Features
• 0.12 dB Insertion Loss
• 0.27 FITS, failures per billion hours
- ground based environment.
Direct Replacement for Brand "X" Standard Size Quads
Test Conditions
• Mounted to horizontal RO4003 test board.
• Ambient Temperature = 25° C.
• Based upon internal test. Results may vary.
MERRIMAC
Total Integrated Packaging Solutions®
Tel: 973.575.1300
Fax: 973.575.0531
www.merrimacind.com

$V_{CE}$ = 15 V and $I_C$ = 25 mA. The DC current gain, $\beta = I_C/I_B$, is not listed in the S-parameter file, but on contacting the manufacturer, suppose that at room temperature $\beta$ = 40. Based on this information, the biasing network of **Fig. 2** was developed.

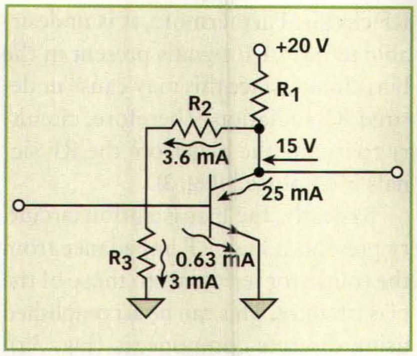
## Applying Microwaves

**JACK BROWNE**
**Publisher/Editor**

Joseph F. White is well known in the microwave industry as an instructor and lecturer. After having received a Ph. D. in electrophysics from Rensselaer Polytechnic Institute (Troy, NY), Dr. White spent 25 years in semiconductor and component engineering at M/A-COM (Burlington, MA) where he earned several patents for microwave design and engineering. He has also received the IEEE's Microwave Theory & Techniques (MTT) Society's annual application award for "Contributions to Phased Array Antennas."

**Joseph F. White**

Upon leaving M/A-COM, Dr. White edited the *Microwave Journal* magazine and then founded his own publication, *Applied Microwave* magazine (later to be renamed *Applied Microwave & Wireless* magazine). In addition to writing the recently published *High Frequency Techniques* for John Wiley & Sons (Hoboken, NJ, 2004), Dr. White, who is a lifetime fellow of the IEEE, also authored *Microwave Semiconductor Engineering*, a textbook in its third printing since 1977, and now published by Noble Publications (Norcross, GA). This article series is excerpted from his new book as well as the one-week technical course that he teaches, entitled "Wireless Engineering."



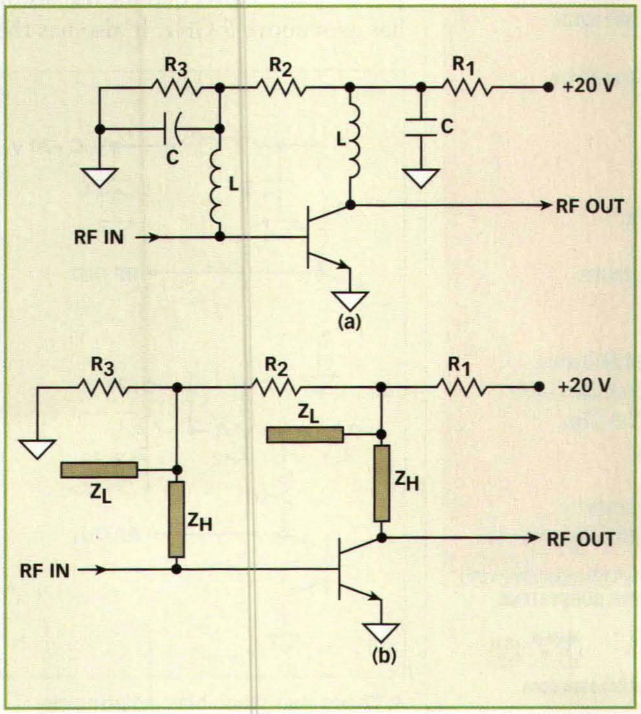

2. This simple single-stage bias network can be used to power the 2N6679A transistor from Motorola.

The resistor values are calculated as follows. A base current of 0.63 mA is required (25 mA/40). However, a shunt path to carry about five times this value, say 3 mA, is desirable so that when the 15-V level falls, the base current will fall nearly proportionately. Since the transistor is a silicon NPN, the base-emitter junction behaves as a silicon diode. Hence, it will have a voltage drop at turn-on of about 0.75 V. The emitter-base shunting resistor can be calculated as:

$$R_3 = \frac{0.75\ V}{3\ mA} = 250\ \Omega \quad (6)$$

$$R_2 = \frac{(15\ V - 0.75\ V)}{3.63\ mA} = 3925\ \Omega \quad (7)$$

$$R_1 = \frac{(20\ V - 15\ V)}{28.6\ mA} = 175\ \Omega \quad (8)$$




3. These example circuits show the use of discrete (a) and printed (b) bias isolation components.

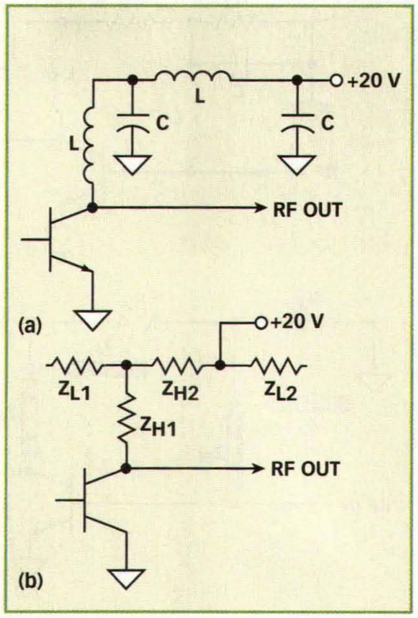
Practically speaking, the closest values of standard resistors may be used. This bias circuit tends to self-compensate with temperature. As temperature increases, the base current increases for a given $V_{BE}$. However, this causes an increase in $I_C$, resulting in a larger voltage drop in $R_1$, and thereby reducing $V_{BE}$.

By themselves, resistors $R_2$ and $R_3$ are large compared to the 50-Ω RF impedance level at the input. However, their parasitic elements may cause them to place an excessive load on the RF circuit. Furthermore, it is undesirable to have RF signals present in the bias circuit, since this may cause undesired RF radiation. Therefore, circuitry to isolate the bias from the RF signals is employed **(Fig. 3)**.

Basically, the bias isolation circuitry presents a high RF impedance from the transistor terminals to those of the bias circuitry. This can be accomplished using discrete components (Fig. 3a). For the present 1 GHz, 50-Ω amplifier example isolating elements of L=100 nH and C = 100 pF might be employed. When space permits the isolating elements can be "printed" as distributed elements along with the RF circuit. The transmission lines are one-quarter wavelength long at the amplifier's RF center frequency. For the 50-Ω amplifier example, the high-impedance lines might be made $Z_H$ = 150 Ω, and the low-impedance lines $Z_L$ = 25 Ω.

Bias isolating networks are crucially important in amplifier design and should not be taken for granted in the design effort. As shall later be seen, transistors may have gain at frequencies well above the design bandwidth. In the present 1-GHz amplifier example, the table shows that the transistor has gain above 5 GHz. It also has the



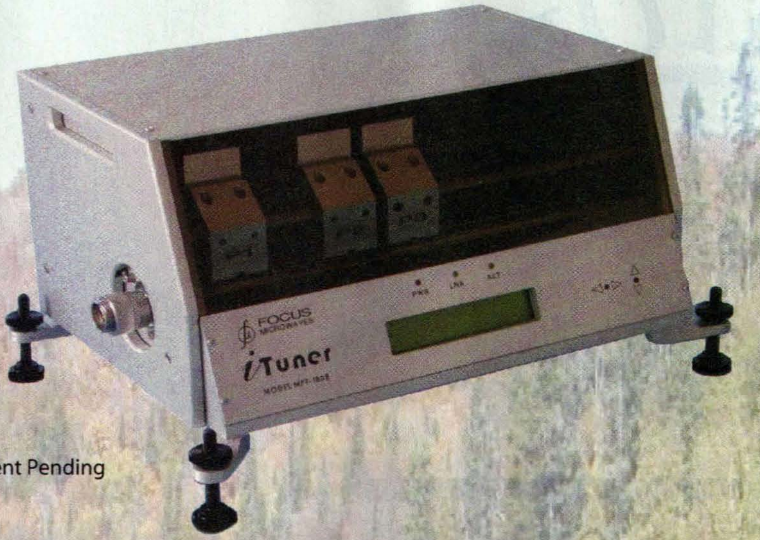



**4. These two-stage bias isolating circuits are based on discrete (a) and printed (b) circuit elements.**

# Why Look any Further?

*Focus* introduces the

## *Multi Purpose Tuner* - MPT*

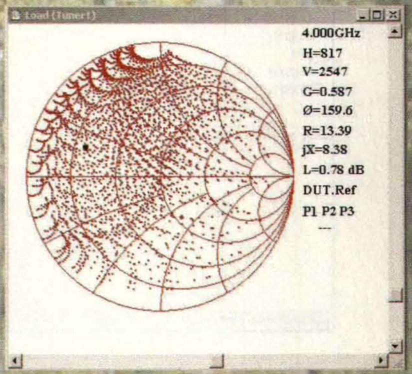


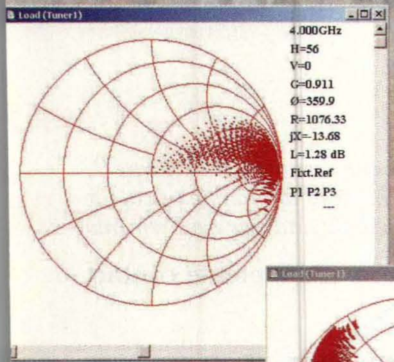

*Patent Pending

A precision electromechanical tuner for Load Pull and Noise measurements, combining:

- Vibration free on-wafer tuning (no horizontal axis movement)
- Multi-octave units in 0.4 - 50 GHz frequency range
- Wideband Fundamental and Harmonic tuning$^{+}$
- High resolution (64 million calibrated tuning points)$^{++}$
- High power (50 W (APC-7), 100 W (N), 200 W (7/16))
- High VSWR (Prematching tuner) more than 100:1 @ 3GHz
- TCP/IP (*iTuner*) control for User developed software

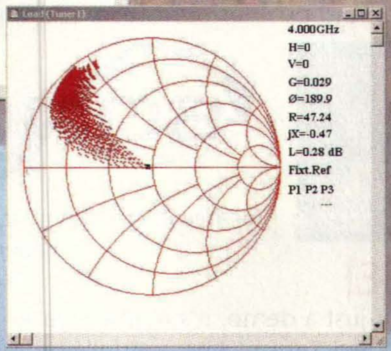
\+ Without Triplexers or Harmonic resonators
++ Calibration time: 20 minutes / set of harmonic frequencies




Using three independent RF probes, the MPT synthesizes several million impedances at the fundamental and harmonic frequencies. This allows independent harmonic tuning, high VSWR prematching and most other crucial tuner features, all in a single unit.

MPT is compatible with all Focus application software. Due to its *iTuner* control, it allows users to develop their own test software using LabView™, Vee™, Visual Basic™, Matlab™, C, C++, etc...




For more details ask for Product Note 78.

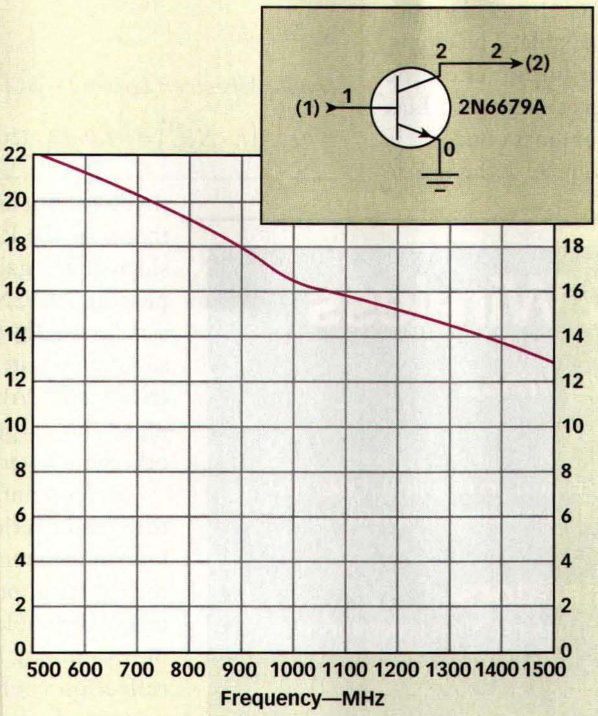
*Focusing highest density of points by adjusting distance between probes*

*he Expert's Choice*

Focus microwaves

1603 St. Regis
Dollard-des-Ormeaux, Quebec
Canada, H9B 3H7

Tel: 514-684-4554
Fax: 514-684-8581
Email: info@focus-microwaves.com
Web: www.focus-microwaves.com




**5. This plot of $S_{21}$ gain from 500 to 1500 MHz was generated for an amplifier based on the 2N6679A transistor using the Genesys suite of computer-simulation tools from Eagleware Corp.**

potential of breaking into oscillation at any frequency for which it has gain (this potential instability will be addressed in the next installment of this article series).

The single-stage bias circuits shown in Fig. 2 have only single high-impedance and low-impedance elements for isolation. They are shown for illustration of the bias isolating methods and are not presented as adequate designs for all applications. Where practical, multistage bias isolation is preferable **(Fig. 4)**.

An informal measure of the effectiveness of the distributed bias structure is to bring a screwdriver tip near the open circuit ends of the bias flags (the open-circuited ends of the low impedance line sections) while measuring the output power of the amplifier. A significant power change experienced when so probing the end of the second bias flag, $Z_{L2}$, indicates the bias circuit may be resonant at the wrong frequency or that more isolating stages are required.

Most commercial

## S-parameter file for the 2N667A bipolar transistor from Motorola[1]

! 2N6679A.S2P

! 2N6679
! VCE = 15V; IC = 25 mA

# GHz S MA R 50

! S-PARAMETER DATA

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0.1 | 0.60 | -76 | 38.6 | 141 | 0.01 | 55 | 0.83 | -20 |
| 0.5 | 0.67 | –158 | 12.7 | 95 | 0.02 | 40 | 0.50 | -27 |
| 1.0 | 0.68 | –178 | 6.6 | 77 | 0.03 | 53 | 0.46 | -32 |
| 1.5 | 0.68 | 170 | 4.4 | 64 | 0.04 | 54 | 0.47 | -41 |
| 2.0 | 0.69 | 162 | 3.4 | 54 | 0.05 | 54 | 0.47 | -50 |
| 2.5 | 0.69 | 154 | 2.7 | 42 | 0.06 | 55 | 0.49 | -59 |
| 3.0 | 0.69 | 146 | 1.3 | 31 | 0.07 | 55 | 0.53 | -70 |
| 3.5 | 0.69 | 138 | 1.9 | 21 | 0.08 | 54 | 0.55 | -79 |
| 4.0 | 0.69 | 131 | 1.7 | 11 | 0.09 | 51 | 0.57 | -89 |
| 4.5 | 0.69 | 123 | 1.5 | 1 | 0.10 | 49 | 0.59 | -97 |

From left to right, the columns show frequency (in GHz), $S_{11}$, $S_{21}$, $S_{12}$, and $S_{22}$, with each parameter contained in two columns [the first is numeric magnitude (not dB) while the second is phase angle (deg.)].

computer-aided-engineering (CAE) circuit simulators can work with an S-parameter table to provide an analysis over frequency, interpolating the data to calculate the circuit behavior between frequencies for which actual measured S-parameter data are available. The circuit evaluation could be performed with bias elements but it is assumed in this article that sufficient bias isolation is achieved that only the RF circuit need be considered. The gain of the present example, using the 2N6679A transistor, was simulated in **Fig. 5** using the Genesys CAE simulation suite from Eagleware Corp. (Norcross, GA). The impedance of the input and output ports is 50 Ω unless otherwise noted.

$$|S_{11}| = 0.68$$

$$Input\ Mismatch\ Loss = 1 - |S_{11}|^2 = 1 - 0.68^2 = 0.54$$

$$= 10 l \log\left(1 - |S_{11}|^2\right) = -2.7 dB \quad (9)$$

$$|S_{22}| = 0.46$$

$$Output\ Mismatch\ Loss = 1 - |S_{22}|^2 = 1 - 0.46^2 = 0.79$$

$$= 10 \log\left(1 - |S_{22}|^2\right) = -1.0\ dB \quad (10)$$

At this point, if this gain is satisfactory (and overlooking for the present time the matter of amplifier stability), the electrical portion of the amplifier design is complete. On the other hand, on examining the input and output reflection coefficients, $S_{11}$ and $S_{22}$, respectively, in the table, it is apparent that a good amount of power is lost to reflection at the input and mismatch at the output. At 1 GHz,

SEE EQ. 9 IN BOX ABOVE

SEE EQ. 10 IN BOX ABOVE

These mismatch losses correspond to 46-percent power loss at the input and 21-percent power loss at the output. Therefore, by matching input and output, as much as 3.7 dB additional gain can be added, with a matched circuit at input and output as well. Next month, Part 2 of this article series will examine the means of matching the transistor to obtain this additional gain and present what is necessary to guarantee unconditional stability. MRF

**EDITOR'S NOTE**

This article is excerpted with permission from the one-week industrial couse, *Wireless Engineering*, that the author teaches and from *High Frequency Techniques, An Introduction to RF and Microwave Engineering*; by Joseph F. White (John Wiley & Sons, Hoboken, NJ, 2004; e-mail: www.Wiley.com).

**REFERENCES**

1. *Genesys 7 Reference Manual*, (Eagleware, Norcross, GA, 1986-2000).

2. Guillermo Gonzalez, *Microwave Transistor Amplifiers, Analysis and Design*, 2nd ed. (Prentice-Hall, Upper Saddle River, NJ, 1984), pp. 273-283.

# Tracking Generators Enhance Spectrum Analysis

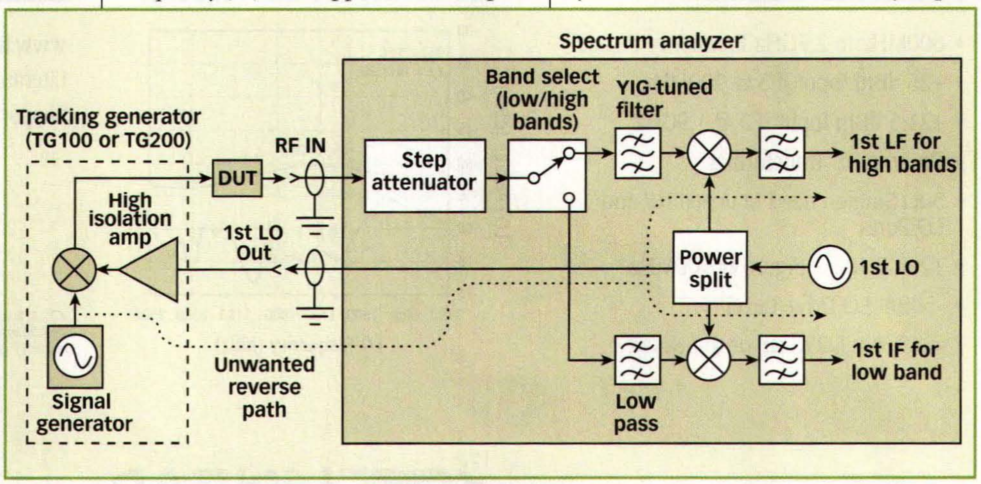
The combination of a tracking generator and a spectrum analyzer enables swept scalar frequency-response measurements of active and passive networks.

**Spectrum analyzers have long been used with tracking generators to perform swept scalar frequency-response measurements on active and passive networks. While many commercial spectrum analyzers can be specified with optional tracking generators, most of these sources only provide a signal for the first band of the analyzer. The method that follows will also cover the first high band of** many spectrum analyzers. A method will also be presented that allows sweeping a device under test (DUT) with internal frequency conversion.

**DAN DOBERSTEIN**
**President**
DKD Instruments, 750 Amber Way, Nipomo, CA 93444; (805) 929-2285, FAX: (805) 929-5983, e-mail: dand@dkdinst.com, Internet: www.dkdinst.com.

**Figure 1** shows a common RF spectrum analyze architecture with the tracking generator function implemented with a mixer, amplifier, and RF signal generator set to a fixed first intermediate frequency (IF). This approach works provided that the analyzer sweeps only the first local oscillator (LO) to achieve the frequency scan. Also, the analyzer must provide a sample output of the first LO. If the analyzer's resolution-bandwidth (RBW) filters (whether analog or digital) are fixed and only the first LO is swept, then this configuration will produce the correct signal.

In this setup, the signal generator is set to the first IF of the band of interest (which can be found from the analyzer manufacturer's data or by exper-




1. This block diagram shows how a tracking generator with high-isolation amplifier can be used with a spectrum analyzer for scalar frequency-response measurements.

imentation). The first IF can be found by using the widest RBW filter and tuning the generator where the analyzer shows a rising noise floor. By switching to narrower RBW filters and tuning the signal generator for peak amplitude, the IF estimation can be made


2. The TG100 system integrates a wideband mixer and isolation amplifier into a single assembly.

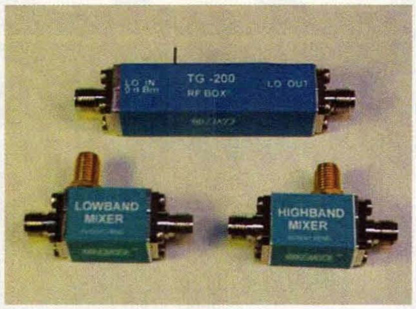


more precise.

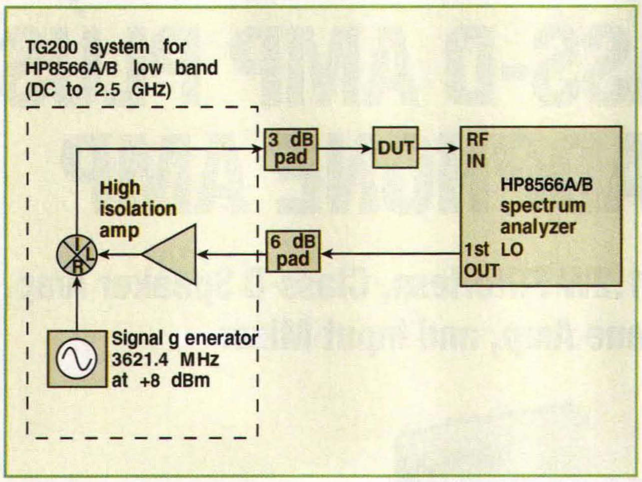
When the analyzer's first LO signal is mixed with the signal generator's replication of the first IF signal, the output of the mixer will contain a frequency component that is exactly the RF signal the analyzer is tuned to at that point in the sweep (the tracking generator signal). The DUT is then placed between the mixer output and the analyzer's RF input. The tracking generator signal will automatically track during sweeps, providing a perfectly synchronized signal for swept scalar measurements.

Although it may be tempting to connect the analyzer's LO output directly to the mixer, this will cause a problem with most analyzers. There is usually not enough isolation in the reverse direction of the first LO output port. As a result, the signal generator's first IF signal leaks into the analyzer's first IF stage, flooding the instrument's first and subsequent IF stages and raising the noise floor.

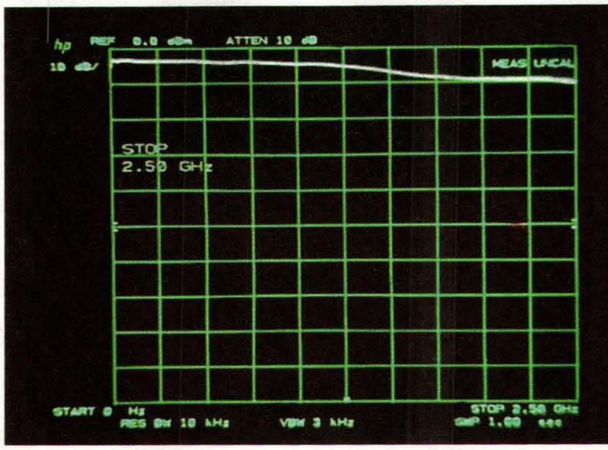
A circulator can provide increased isolation (about 20 dB) but reduce first LO power to the mixer. A better approach is a high-isolation amplifier to provide as much as 50-dB isolation to about 6




3. The TG200 system employs low- and high-band external mixers with a separate isolation-amplifier assembly.




4. In this configuration, the TG200 system and HP 8566 analyzer are set up for low-band (DC to 2.5 GHz) measurements.

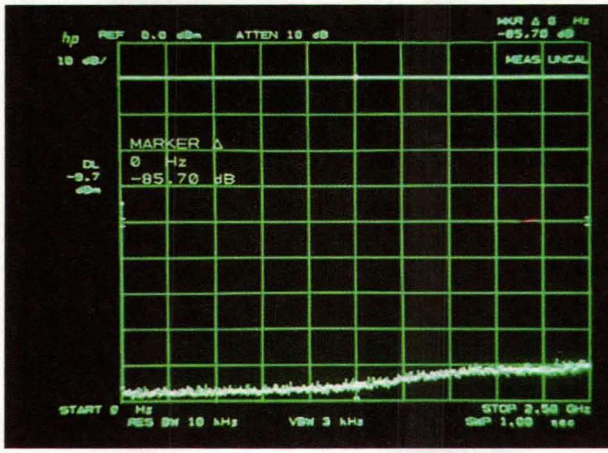



5. This spectrum-analyzer uncorrected trace shows the measurement of a through-line section from DC to 2.5 GHz using the TG200 system with the HP 8566A/B.

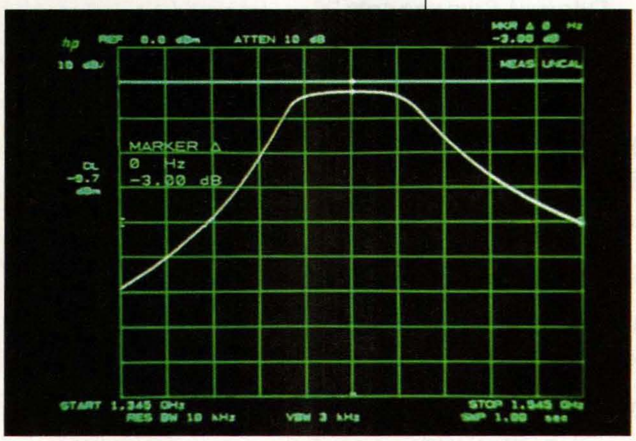
GHz. In addition, it allows broadband operation and good LO drive level when only low first LO level is available. The high-isolation amplifier is designed to work with 0-dBm input power.

This improved approach and the configuration of Fig. 1 are the basis for two tracking-generator systems developed by DKD Instruments. In one (model TG100), the mixer and high-isolation amplifier are integrated into a single assembly **(Fig. 2)**. In the other (model TG200), the amplifier is a separate module, allowing the use of different mixers for the low and high bands of a particular analyzer **(Fig. 3)**. The former operates from 500 kHz to 2.6 GHz with a first high-band range of about 2.0 to 4.5 GHz. The latter uses one mixer for the low band (to 2.6 GHz) and one for the first high band (to 6 GHz). Both systems are optimized for 0-dBm power. Adding a doubler to the first LO and the appropriate mixer could also serve the second high band (a doubled first LO) of many analyzers, with range beyond 10 GHz for many instruments.

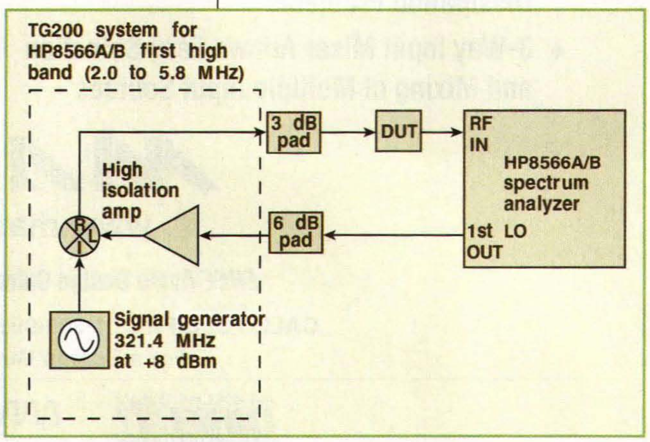
**Figure 4** shows the second type of tracking generator system with an HP 8566A/B spectrum analyzer from Agilent Technologies (Santa Rosa, CA). The generator is set up to cover the instrument's first band (DC to 2.5 GHz). The instrument's first IF in the low band is 3621.4 MHz, and the signal generator is set to this frequency at a level of about +6 dBm. In this configura-




6. This spectrum-analyzer trace shows the noise floor of the TG200/8566A/B combination with 50-Ω terminations.




7. This trace shows the scalar frequency-response plot of a bandpass filter measured from 1.345 to 1.545 GHz.




8. In this configuration, the TG200 system and HP 8566 analyzer are set up for first high-band (2.0 to 5.8 GHz) measurements.


NEW
> Exceptionally Low Phase Noise
> Ultra Wide Tuning Range
> Excellent Thermal Stability
> Simplifies Design
... Better Value
> Power Efficient
Harmonic Suppression
Tuning Sensitivity
Output Power
-99 dBc/Hz @ 10 kHz
500-1700 MHz
VCO
-92 dBc/Hz @ 10 kHz
1500-3500 MHz
VCO
-90 dBc/Hz @ 10 kHz
1800-4200 MHz
VCO
-112 dBc/Hz @ 10 kHz
350-1100 MHz
VCO
DISTRIBUTED
COUPLED
VCO
DCMO
SERIES
DCFO
SERIES
Phase Noise Plot (350-1100MHz)
5V,30mA
12V,30mA
Phase Noise
DETAILED SPECIFICATIONS
ARE AVAILABLE FOR DOWNLOAD AT
WWW.SYNERGYMWAVE.COM
For additional information,
contact Synergy's sales and application team.
201 McLean Boulevard, Paterson, NJ 07504
Phone: (973) 881-8800 Fax: (973) 881-8361
E-mail: sales@synergymwave.com
World Wide Web: www.synergymwave.com
SYNERGY®
MICROWAVE CORPORATION

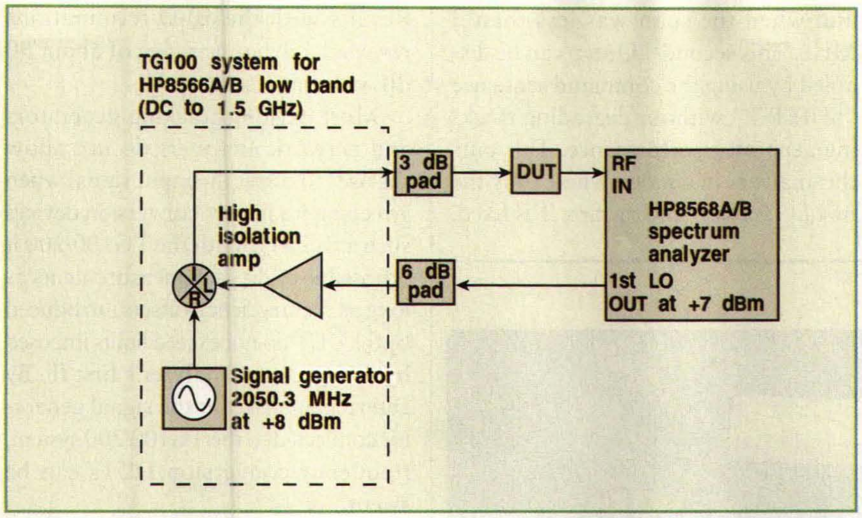
tion, the signal generator is fed to the R-port of the mixer, the first LO sample to the L-port, and the I-port contains the tracking-generator output signal as the difference product. The sum product will also be incident on the DUT input but is at 2(3621.4 MHz) = 7242.8 MHz or higher. The 3-dB pad on the I-port improves the VSWR that the DUT sees looking back toward the tracking generator. The 6-dB pad lowers the LO signal from the HP 8566 (nominally +8 dBm) to a more optimum 0 dBm for the tracking generator systems.

The test setup was used to measure a through transmission line as the DUT from DC to 2.5 GHz **(Fig. 5)**. The uncorrected plot shows a roll off of about 7 dB from the low end to the high end with the RBW filter manually set to 3 kHz

> ***By entering an offset at the signal generator connected to the TG100/200 system, frequency-conversion DUTs can be swept.***

and video-bandwidth (VBW) and sweep time set manually. When the through-line DUT was replaced by 50-Ω terminations on the analyzer input and tracking generator output, the noise floor could be seen in a dynamic range exceeding 80 dB **(Fig. 6)**. The analyzer is subtracting out (in video) the roll off in the through-line response of Photo 1. The result of the video subtraction is that a through-line connection results in a flat trace. Because the correction is accomplished via video memory [VIDMEM_A- (VIDMEM_B-DL)], the noise floor rises at the high end due to the roll off in photo 1. Therefore, using a RBW of 3 kHz, signal level of +8 dBm at 3621.4 MHz, internal attenuation of 10 dB, and the 3-dB pad on the I-port, a dynamic range of approximately 80 dB is possible.

The selection of an analyzer RBW is primarily governed by the quality of



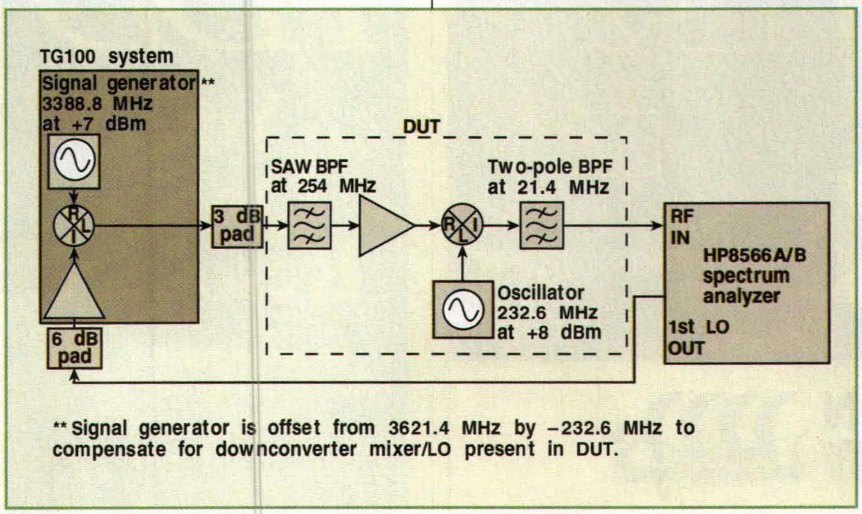

**9. In this configuration, the TG100 is teamed with an HP 8568A/B analyzer for low-band (DC to 1.5 GHz) measurements.**

the signal generator. For an unstable source such as an unlocked cavity generator, narrowest RBW filter that can be used is about 100 kHz. A more stable source allows the use of narrower RBW filters. Of course, with a wider RBW filter, the noise floor will rise and the dynamic range will drop.

The low-band tracking-generator system was used to measure a bandpass filter with center frequency of 1445 MHz **(Fig. 7)**. The start frequency was 1345 MHz and the stop frequency was 1545 MHz. The vertical scale is 10 dB/div, and the analyzer was set for 10-dB attenuation, 1-s sweep time, 10-kHz RBW, and 3-kHz VBW. Before the trace was taken, the reference line was set by using video subtraction to remove the variation in tracking-generator output level.

**Figure 8** shows the TG200 setup for creating a tracking-generator signal for the first high band of the HP8566 spectrum analyzer. For high-band operation, the I-port of the mixer is connected to the signal generator. The analyzer's first IF for all high bands (2 to 22 GHz) is 321.4 MHz (to which the signal generator is tuned). The mixer's R-port now contains the desired tracking-generator signal and its unwanted image. The YIG tracking filter at the analyzer's input will effectively eliminate this unwanted image signal.

**Figure 9** shows a TG100 system for




**10. This setup allows the signal generator to be offset for evaluating frequency-translation devices with the TG100 system and an HP 8566A/B analyzer.**

the low band of the HP 8568A/B spectrum analyzer (DC to 1.5 GHz). The analyzer's first IF is nominally at 2050.300 MHz (the frequency to which the signal generator is tuned) with fixed second LO, although the second LO shifted for certain portions of the sweep and when the span was less than 2 MHz. This second-LO step can be disabled by using the command sequence "SHIFT T" without degrading tracking-generator performance. This puts the analyzer in a mode where only the first LO is swept and the first IF is fixed.

Results with the 50-Ω terminations revealed a dynamic range of about 90 dB with this test setup.

Most existing tracking generators and network analyzers do not allow the user to offset the input signal when sweeping frequency-conversion devices such as mixers. With the TG100/200 it is possible to do such measurements as long as the frequency offsets introduced by the DUT do not exceed limits imposed by the spectrum analyzer's first IF. By entering an offset at the signal generator connected to the TG100/200 system, frequency-conversion DUTs can be swept.

As an example, the TG100 module was used with the HP 8566 to sweep a frequency downconverter **(Fig. 10)**. Normally, to use the TG100 with the HP8566 in its first band, the signal generator would be set to 3621.4 MHz. But since the DUT in this example has a mixer with a LO at 232.6 MHz, this must be compensated for, otherwise the tracking generator signal will be incorrect. The solution is to offset the signal generator by –232.6 MHz, resulting in an output frequency of 3388.8 MHz. This puts the tracking generator output at the correct frequency for this DUT's particular internal frequency offset. MRF

## Software Simulates MEMS Capacitive Switch

MICROELECTROMECHANICAL SYSTEMS (MEMS) can be thought of as miniature mechanical components fabricated with a semiconductor process. Since they share the traits of both mechanical and electrical devices, they pose a challenge for simulation programs to model. Fortunately, the APLAC MEMS Module is a computer-aided-engineering (CAE) tool developed for this purpose and supported by an application note from APLC, "Simulating a Micro-electro-mechnaical Capacitive Switch using APLAC MEMS Module."

The software module is a physics-based simulation tool written for efficient and robust modeling of the electical and mechanical characteristics of MEMS components. The program uses the equivalent-circuit approach to modeling, so tha all analysis modes, including AC, DC, transient, and harmonic-balance approaches, are available. The MEMS models work in parallel in multiple physical domains, enabling simultaneous electrical, mechanical, thermal, and gass-flow simulations.

The component covered in the application note is a MEMS capacitive switch designed by a firm associated with the cellular telephone, Nokia. The note includes details on the material properties of the MEMS device, including the length, width, and height of the switch bridge, the length of the lower electrode, the height of the isolating layer, and surface roughness.

The APLAC software module includes a component called CapacitiveSwitch which models the mechanical and electrical properties of the switch. The software, which can simulate the capacitance-voltage (C-V) characteristics of the device, can alter the bias voltage needed to change the switch state and simulate the switching speed of the structure during dynamic analysis. The software, which includes the effects of stray capacitance, divides the symmetrical switch structure into 50 sections to speed the modeling process; the note points out that in the case of an asymmetrical design, a longer modeling process is required. Copies of the four-page application note are available for free download from the company's website.

**APLAC Solutions, Inc., P.O. Box 140008, Irving, TX 75014-0008; (972) 719-2562, FAX: (972) 719-2568, Internet: www.aplac.com.**

*The software module is a physics-based simulation tool written for efficient and robust modeling of the electrical and mechanical characteristics of MEMS components .*

## Testing For Communications Interference

SIGNAL INTERFERENCE can adversely affect the performance of a communications system. Fortunately, powerful and easy-to-use tools such as the Spectrum Master MS2711B portable spectrum analyzer from Anritsu Co. (Morgan Hill, CA) helps engineers and technicians measure signal interference before it can disrupt communications system service.

The note opens with a section on connecting the field spectrum analyzer to the system under test, using several examples of communications systems, including a cellular base station and a microwave data link. The literature details some of the built-in measurement functions in the MS2711B which can be used for finding sources of interference, such as maximum hold and marker peak functions, as well as a built-in preamplifier to boost sensitivity when evaluating low-level signals and an integral demodulator which can process signals with amplitude modulation (AM) and frequency modulation (FM).

The detailed note covers information on evaluating systems with various antenna types and accessories and shows how to measure field strength, occupied bandwidth, and channel power. It also reviews several basic types of interference, including licensed interferers, intermodulated signals, and harmonic signals.

The application note features several useful examples of field measurements with the compact analyzer, including diagnosing desensitization effects from an interferer, studying interference in cellular base stations, cellular base-station interference testing, and how to set up a directional signal survey with the analyzer. This latter measurement is made with the analyzer's own omnidirectional antenna and by selecting the proper measurement band of interference to match the location of a suspected high-power interferer. Copies of the 12-page application are available for free download from the company's website.

**Anritsu Co., Microwave Measurements Div., 490 Jarvis Dr., Morgan Hill, CA 95037-2809; (800) ANRITSU, Internet: www.us.anritsu.com.**

cover story

# Software Speeds Complex IC Design

This new simulation and analysis tool provides a high degree of accuracy and transistor-level detail while performing computations at five to ten times the speed of existing CAE tools.

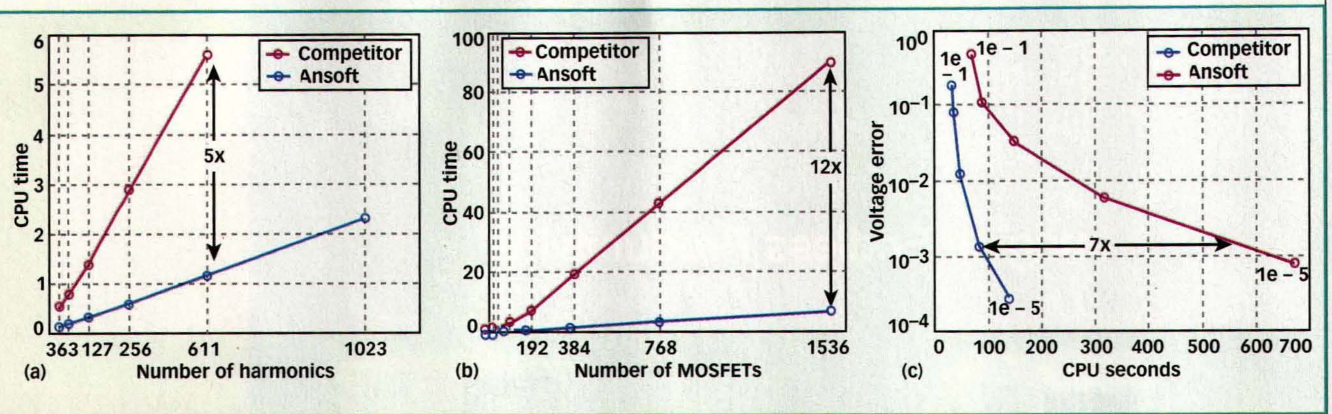
**Consumer demand for greater functional integration in wireless and Internet-enabled products drives an increased adoption of CMOS and SiGe technologies for high-performance circuit design. This leads to a beneficial reduction in device footprint, cost, and power consumption but dramatically increases devices counts (10x to 100x). These larger, more complex circuits require detailed circuit simulation including transistor (SPICE) level accuracy to properly capture the analog/RF behavior at the higher operating frequencies. In addition, time-domain** (transient) and frequency-domain (harmonic balance) simulations must be performed from the identical circuit netlist using the identical device models to guarantee consistent results.

Nexxim from Ansoft represents the "next state-of-the-art" for detailed circuit simulation and verification for a new generation of complex high-

**DEEPAK RAMASWAMY**
Scientist
**MARK REICHELT**
Director of Nexxim R&D
**MARY TOLIKAS**
Director of Business Development
**Z.Y. DANIEL WU**
Analog/Mixed-Signal IC Specialist
Ansoft Corp., 225 West Station Square Dr., Suite 200, Pittsburgh, PA 15219; (412) 261-3200, FAX: (412) 471-9427, e-mail: info@ansoft.com, Internet: www.ansoft.com.

Comparing Nexxim with analysis options

| APPLICATION | NUMBER OF DEVICES | ANALYSIS TYPE | CURRENT TOOLS | NEXXIM | PERFORMANCE ADVANTAGE |
|---|---|---|---|---|---|
| Mixer (SiGe) | 50 active 230 total | DC | No convergence | 17 s | Infinite |
| Bluetooth receiver front end (BiCMOS) | 2500 active 4800 total | Multi-tone harmonic balance | 8 h | 30 min | 16x |
| Phase locked loop (CMOS) | 1412 active 1432 total | Transient | 2 days | 10 h | 5x |
| Frequency divider (GaAs) | 14 active 34 total | Single-tone harmonic balance | No convergence | 32 s | Infinite |
| Analog-to-digital converter with no parasitics (SiGe) | 640 active 96,500 total | Transient | 6 h | 37 min | 10x |
| Analog-to-digital converter with parasitics (SiGe) | 12150 active 345600 total | Transient | Cannot parse netlist (too large) | 4 h | Infinite |
| SRAM cell (CMOS) | 96,000 active 128,000 total | Transient | No convergence | 5.5 h | Infinite |




**1. Nexxim scales extremely well for large problems in both the time and frequency domains.**

performance ICs. Nexxim delivers orders of magnitude improvement in simulation speed, accuracy, and capacity. Nexxim combines with Ansoft Designer and HFSS to provide a total solution for circuit design, circuit/system co-design, and post-layout verification including on-chip/embedded passives.

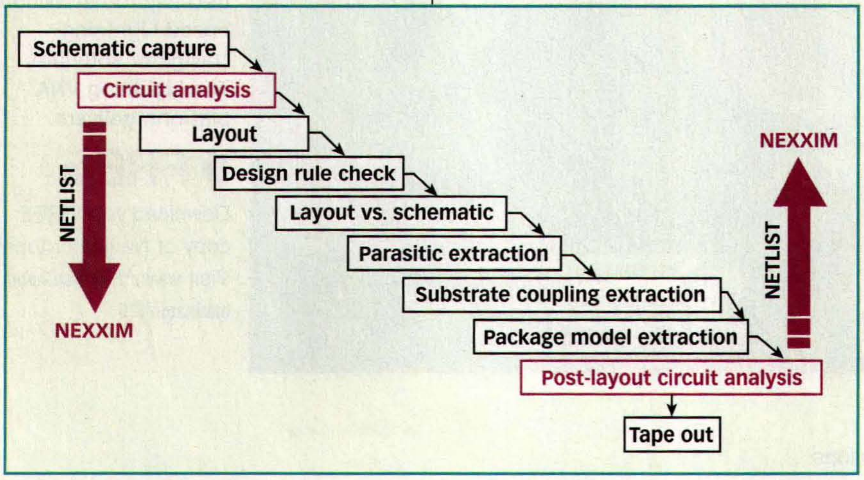
The **table** illustrates the performance advantage of Nexxim relative to current tools. As shown in **Fig. 1**, the software is designed for large, complex circuits: Nexxim's simulation speed advantage increases as the number of harmonics and number of transistors in the circuit increase; in other words, the larger the problem, the greater Nexxim's performance advantage. Likewise, Nexxim demonstrates a much steeper "accuracy versus simulation time" curve than existing tools; its speed advantage increases as the required solution accuracy increases.

Nexxim is easily incorporated in the typical IC design flow to perform circuit analysis **(Fig. 2)**. A netlist describing a circuit of interest at its pre-layout verification phase can be exported from within a design environment and imported into Nexxim for solution. The same applies for the post-layout verification phase; the extraction of local parasitics, crosstalk, interconnect delays, and substrate noise add significantly more elements to the design and augments the netlist size. This netlist can be also exported from within the design environment and imported into Nexxim for solution.

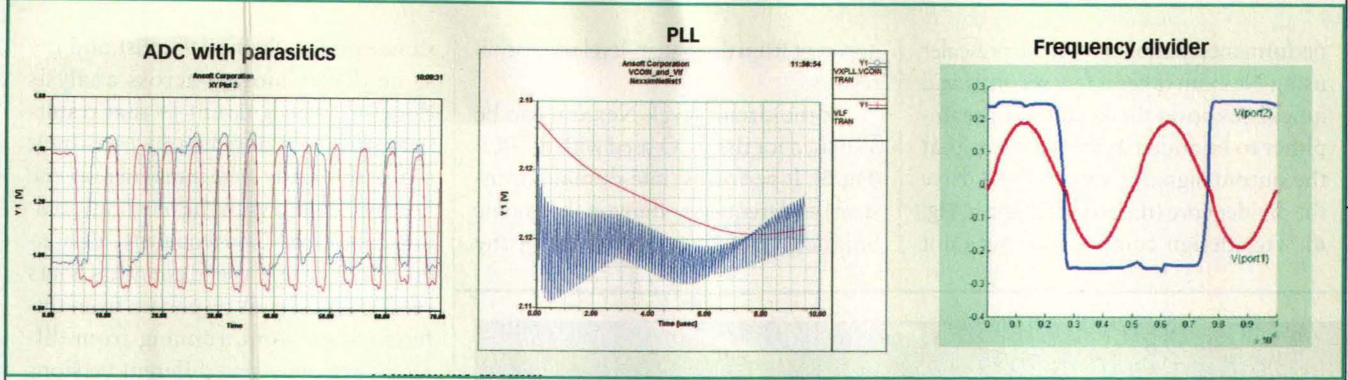
An example of the different designs tackled by Nexxim is an analog-to-digital converter (ADC), where the effects of layout parasitics, substrate coupling and packaging result in a large circuit that includes tens of thousands of transistors and passive elements to be accurately analyzed **(Fig. 3)**. Even for a circuit of this complexity, Nexxim's large capacity and fast speed provide transient solutions within minutes, allowing large parametric simulation runs to be performed within a reasonable time frame. As a result, thermal effects and process variations can be taken into account to ensure that the most optimal design architecture is used during an IC process run.

Even a small design such as a 100-MHz frequency divider with 14 active devices provides a challenge for frequency-domain simulations using current CAE tools. The output of the divider approximates a square wave, requiring the use of many harmonics for accurate characterization. By performing single-tone and multi-tone harmonic balance analyses that incorporate Krylov subspace methods, Nexxim can simulate the performance of the frequency divider quickly and accurately. Proprietary preconditioning algorithms help achieve fast convergence, and a multi-tone harmonic-balance simulation can be run with an option that uses minimal memory (often a cause for concern in circuits with many variables and harmonics).

The speed of Nexxim is apparent in the simulation of a phase-locked loop (PLL). Using current tools, about two days are needed to simulate the performance of a 430-MHz PLL circuit on a 0.15-µm CMOS process, even if the lock voltage and frequency are set very close to their final values during simulation. Nexxim uses a new variable-time-step integration formula combined with advanced error estimation and control to decrease the solution time five times to provide greater accuracy while




**2. Nexxim is easily incorporated in the IC design flow to perform circuit analysis in the pre- and post-layout verification phases.**




**3. Nexxim performs fast transient and harmonic balance analyses for a variety of applications.**

requiring fewer time points over the simulation time interval. A new sparse matrix solver specifically optimized for circuit simulation applications speeds solutions for all time points.

For high-level designs, the combination of Nexxim and Ansoft Designer allows operators to literally "toggle" between aspects of a circuit. Ansoft Designer's system simulator can be used to size the various system components and Nexxim can be applied to "fine-tune" the design, by performing detailed and accurate circuit-level analysis of each of the components at high simulation speed. The combination was applied to the co-design of an integer-N PLL based on a 0.25-µm CMOS process (for GSM 1800). Ansoft Designer simplifies the sizing of the prescaler residing in the PLL's counter, while Nexxim handles the analysis of the prescaler at the circuit level. The overall circuit contains 182 BSIM3v3.2 transistors, readily available from Nexxim's extensive device model library. Nexxim is compatible with the golden standards in device models and netlist formats. It also provides designers with the capability of rapidly incorporating their own proprietary models; their run-time efficiency matches that of already existing, built-in models so as to not compromise simulator

performance. Simulation of the prescaler using Nexxim takes a few seconds and quickly exposes the need for a preamplifier to be added in the design so that the output signal is sufficient to drive the divider core (the red solid line in **Fig. 4**). This design complication was not apparent from the system-level simulation results.

At the circuit level, Nexxim can be also used for the VCO used with the PLL **(Fig. 5)**. It performs time-domain (transient) and frequency-domain (harmonic balance, AC) simulations using the same circuit schematic/netlist and the same device models across analysis domains. This guarantees that results in the different domains are consistent so that the steady-state transient response is in agreement with the harmonic balance solution. Consequently, designers do not have to spend countless hours reconciling circuit responses from different simulators, running from different netlists, using different versions of device models.

After verifying the performance of the individual PLL functional blocks, the whole system is brought together into one circuit and Nexxim is used to verify the overall PLL response. Nexxim takes approximately 19 h to run a transient simulation within 20-µs of the whole system. This is faster, more accurate and without the large waveform discontinuities present in the results of current simulations tools, which take over a week to produce a result.

Given continuing expansion of wireless applications, and with technology scaling down towards 90- and 65-nm feature sizes, accurate simulations must include noise and electromagnetic (EM) effects. Nexxim dynamically links with Ansoft's HFSS full-wave three-dimensional (3D) EM solver to obtain accurate S-parameter or equivalent-circuit models of IC packages, passive elements, and other complicated layout geometries. Through a simple interface window, user-defined primitives of on-chip passive components allow the automatic definition of fully parameterized, on-chip passive configurations. Parameters such as diameter, number of turns, trace-width, and the spacing between traces can be edited via a property window and the passive components can be quickly analyzed and incorporated into the circuit (through S-parameter or W-element representation) for subsequent simulation by Nexxim. In turn, Nexxim incorporates proprietary S-parameter and W-element implementations that allow for accurate frequency- and time-domain simulations of these frequency-domain specified elements. Nexxim provides the

*(continued on p. 104)*

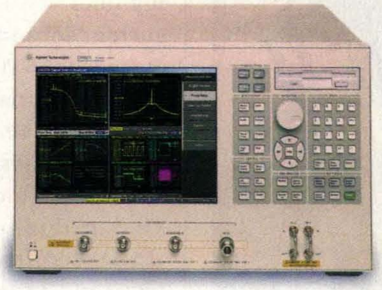
# Instrument Evaluates Oscillator Performance

This compact, multifunction instrument evaluates oscillator and source noise, transients, tuning linearity, and output power from 10 MHz to 7 GHz.

JACK BROWNE
Publisher/Editor

**Oscillator and synthesizer designers struggle to measure key performance parameters for their components, such as phase noise and tuning linearity. They often rely on large racks of single-function test gear, such as power meters and power supplies, to perform difficult measurements. But the E5052A signal source analyzer from Agilent Technologies (Santa Rosa, CA) should bring a sigh of relief to these** designers because this all-in-one instrument can measure the performance characteristics of nearly every type of signal source from 10 MHz to 7 GHz over a wide range of offset frequencies.

The versatile E5052A Signal Source Analyzer **(see figure)** was one of the outstanding products introduced at the recent Microwave Theory & Techniques Symposium (MTT-S) in Fort Worth, TX. The analyzer employs a proprietary cross-correlation measurement method, using two measurement channels with independent reference sources and performing analysis on the two-channel signals. If the two signals are correlated and vector summed, the vector (amplitude and phase) of the two signals will be emphasized. Cross-correlation can remove the limitation imposed by the noise floor of a reference source, allowing measurements of extremely low noise levels.



**The E5052A Signal Source Analyzer is a versatile oscillator and synthesizer tester with carrier range of 10 MHz to 7 GHz and offset range of 1 Hz to 40 MHz.**

The E5052A performs from 1 to 10,000 correlations to lower the noise floor, enlisting the help of digital signal processing (DSP) to derive accurate frequency and amplitude information. As with averaging, the phase-noise sensitivity improves with the number of correlations: for example, 10 correlations yields a 5-dB improvement in the noise floor improvement, while 10,000 correlations provide a 20-dB improvement in the noise floor.

Normally, techniques like averaging and cross correlation add time to a measurement. But in the E5052A, a 100-MHz digital-to-analog con-

## The E5052A at a glance

| | |
|---|---|
| Carrier frequency range | 10 MHz to 7 GHz (110 GHz with downconverters) |
| Measurement capabilities | Phase noise, transients (frequency, phase, and power versus time), power, frequency, and DC current |
| Phase-noise testing | |
| Offset frequency range | 1 Hz to 40 MHz |
| Noise sensitivity | Less than –178 dBc/Hz |
| Measurement method | Two-channel cross correlation |
| Transient testing | |
| Parameters | Frequency, phase, and power versus time |
| Time resolution | 10 ns to 160 µs |
| Frequency resolution | 5 Hz to 7 kHz (heterodyne mode) |
| Frequency transient range | 1.6 to 25.6 MHz (heterodyne mode) 4.8 GHz max. (direct mode) |
| Pretrigger capability | -80 percent of time span or +1 s |
| DC testing | |
| Parameters | DC current (DUT power only) |
| DC sources | –15 to +35 VDC for control voltage, with maximum of 20 mA current |
| | 0 to +16 VDC for power voltage, with maximum of 80 mA current |

verter (DAC) is used with a DSP-based stepped Fast Fourier Transform (FFT) to speed the calculations.

The instrument measures the spectral content for carrier signals of 400 MHz and greater at offset frequencies from 1 Hz to 40 MHz. For carrier signals below 400 MHz, the offset range is 1 Hz to 10 percent of the carrier frequency. The phase-noise sensitivity is typically –164 dBc/Hz offset 40 MHz from a 7-GHz carrier and –174.5 dBc/Hz offset 40 MHz from a 10-MHz carrier when putting + 5 dBm signal, and it can be extended as low as –178 dBc/Hz with the cross-correlation technique **(see table)**. The measurement accuracy is typically ±4 dB for offsets from 1 Hz to 1 kHz, ±2 dB for offsets from 1 kHz to 1 MHz, and typically ±3 dB for offsets greater than 1 MHz.

In addition to phase noise, the E5052A measures tuning linearity, output power, frequency, transients, and current consumed (see table). Its frequency range can be extended to 110 GHz by external downconverters. It offers improved capabilities compared to the company's existing source-measurement solution, the 4352S VCO/PLL Signal Test System, at a fraction of the cost and size. The E5052A includes a Windows-style operating interface, 10.7-in. thin-film-transistor (TFT) liquid-crystal-display (LCD) screen with touch-sensitive (touch-screen) surface, and programming via SCPI or Microsoft Visual Basic for Applications (VBA). Connectivity is via GPIB, USB, and Ethernet. P&A: From $75,000; 30 days. **Agilent Technologies, Test and Measurement Organization, 5301 Stevens Creek Blvd., MS 54LAK, Santa Clara, CA 95052; (800) 829 4444 ext. 7799.**

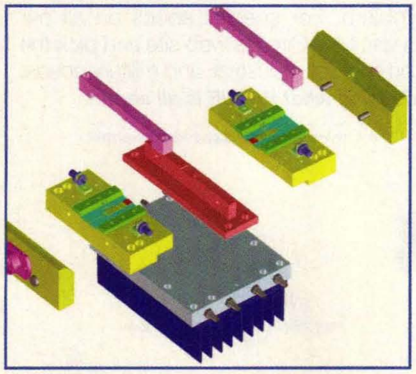

Directional/Bi-Directional
LTCC COUPLERS
5 to 4200MHz
from $1.69* ea. Qty.1000
IN STOCK
Mini-Circuits coupler families offer versatile, low cost solutions for your needs ranging from connectorized versions to the smallest couplers in the world! Choose from 50&75 ohm directional and bi-directional couplers in LTCC packages and rugged connectorized designs with flat coupling ranging from 6-22dB. Mini-Circuits BLUE CELL™ technology offers the world's most highly evolved LTCC technology so you can count on minimal insertion loss and high directivity with models able to handle up to 65W. For today's small design requirements, there's our BDCN series, a 0.12"x0.06" chip. With our LTCC designs, ESD is no longer a problem. For specific specs on all our LTCC couplers, you can visit Mini-Circuits web site and pick the best couplers for your commercial, industrial, and military needs.
Mini-Circuits...we're redefining what VALUE is all about!
Detailed Performance Data & Specs Online at: www.minicircuits.com/dcoupler.html
Bi-Directional
Directional
BDCN .12"x.06"x.03" $2.99 ea. (Qty.25)
BDCA .25"x.30"x.07" $5.95 ea. (Qty.25)
BDCA/BDCA1 .30"x.25"x.04" from $3.95 ea. (Qty.25)
Blue Cell™ Models
DBTC* .15"x.15"x.15" $1.99 ea. (Qty.25)
ZX30 .74"x.50"x.54" $29.95 ea. (Qty.1-9)
Z30 1.25"x1.25"x.75" $29.95 ea. (Qty.1-9)
DBTC: Blue Cell™ ZX30/Z30: Blue Cell™ Inside
U.S. Patent 6140887. Add'l Patents Pending.
NEW!
FREE 2004 Blue Cell™ LTCC Handbook Now on CD!
Mini-Circuits®
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE
The Design Engineers Search Engine Provides ACTUAL Data Instantly From MINI-CIRCUITS At: www.minicircuits.com
ISO 9001 ISO 14001 CERTIFIED
396 Rev A
See our 244 page RF/IF Designer's Guide in EEM (Electronic Engineers Master)

# Fixtures Accurately Test High-Power Transistors

With interchangeable components to handle a wide range of devices, these fixtures address the unique needs of characterizing high-power transistors.

**Power transistors are the building blocks of the high-power amplifiers (HPAs) at the heart of second- and third-generation cellular base stations. Characterizing these devices is often considered a fine art, although the HTF Series of high-power transistor test fixtures from Intercontinental Microwave (Santa Clara, CA) helps restore science to the measurement process. These precision fixtures offer good** RF performance with high measurement repeatability. Their interchangeable components can accommodate nearly any device package and connector combination. The fixtures can be fabricated with several substrate options and connector types for power-handling capability exceeding 200 W CW for both packaged and chip (with adapters)transistors.


**WERNER SCHUERCH**
**President**
Intercontinental Microwave, 1515 Wyatt Dr., Santa Clara, CA 95054-1586; (408) 727-1596, FAX: (408) 727-0105, e-mail: sales@icmicrowave.com, Internet: www.icmicrowave.com.

**The HTF Series fixtures for high-power transistor testing have interchangeable components that make it possible to accept nearly any device and connector combination.**

The HTF Series fixtures **(see figure)** include both 50-Ω models with broad bandwidths and prematched fixtures (such as 11 Ω) for narrowband (several hundred megahertz) testing. Users can tailor a test fixture to a device under test (DUT) by selecting different fixture component parts. Building a fixture involves selecting a midsection that is the correct width and mounting height for the DUT. Then, the launch assembly is chosen (either 50 Ω or a specific matched circuit). Pusher assemblies are also selected for the fixture input and output sides to match the width of the transistor tab. A transition is then chosen with the connector type and RF pin to match the size of the microstrip launch. A base plate, heat sink, and through-reflect-line (TRL) calibration standards round out the configuration.

Fixtures can be fabricated with different substrates, including soft boards, 25- and 50-mil alumina, and customer-defined substrates. The frequency coverage can be as wide as DC to 18 GHz. A series of TRL calibration standards is available based on both FR-4 and alumina for applications from DC to 4 GHz and DC to 26.5 GHz, respectively. The FR-4-based calibration standards are available matched to 50 Ω while the alumina standards can be specified to 11 or 50 Ω.

The HTF Series midsection can handle flanged or flangeless transistor package types. A special clamping mechanism ensures proper heat transfer. A heat sink created for the HTF Series can also be used, which allows fan cooling.

The HTF Series fixtures are available with a variety of different connector types, including APC-7, APC-3.5, SSMA, Type N, and 7/16 EIA connectors. **Intercontinental Microwave, 1515 Wyatt Dr., Santa Clara, CA 95054-1586, (408) 727-1596, FAX: (408) 727-0105, e-mail: sales@icmicrowave.com, Internet: www.icmicrowave.com.**

# POWER DIVIDERS
## DC to 10GHz

## 2 to 32 Way from $49.95 ea. (Qty. 1-9)

Looking for a "perfect fit" power divider for your 50 or 75 ohm design...*f a s t?* Just call Mini-Circuits! Our quick response and wide variety can provide on-target performance to match your needs exactly. That's because we've developed a vast inventory of low cost/high value SMA, BNC, and Type-N connectorized units covering cellular, GSM, ISM, PCS, and satellite bands. Select from 2 to 32way models, wide band units, microstrip designs going down to 470MHz, and resistive dividers going down to DC. And Mini-Circuits power dividers are built tough to handle high matched power with good VSWR, low insertion loss, and high isolation between ports. Mini-Circuits also offers an extensive family of torroidal transmission line power splitters and combiners with frequencies as low as 500Hz. If you're looking for a better blend of usability and affordability, put the *power* of Mini-Circuits to work for you today!

***Mini-Circuits...we're redefining what VALUE is all about!***

*Over 400 Standard Off-The-Shelf Models* **IN STOCK**

| Series | Freq. Range (GHz) |
|---|---|
| 2WAY-0° | 0.50-10.0 |
| 2WAY-90° | 1.00-4.20 |
| 2WAY-180° | 1.00-2.49 |
| 2WAY-0° Resistive | DC-4.20 |
| 3WAY | 0.50-4.20 |
| 4WAY | 0.47-8.40 |
| 5WAY | 0.50-1.98 |
| 6WAY | 0.80-5.00 |
| 7WAY | 0.85-1.99 |
| 8WAY | 0.50-8.40 |
| 9WAY | 0.80-4.80 |
| 10WAY | 0.75-2.40 |
| 12WAY | 0.50-4.20 |
| 14WAY | 0.90-0.99 |
| 16WAY | 0.47-4.80 |
| 32WAY | 0.95-1.75 |

*For detailed model numbers, specifications, and prices, consult our web site, RF/IF Designer's Guide, CD-ROM, or call Mini-Circuits.*

*Detailed Performance Data Online at:* ***www.minicircuits.com/splitter.html***

**Mini-Circuits®**

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For quick access to product information see MINI-CIRCUITS CATALOG & WEB

YONI™ ***The Design Engineers Search Engine** Provides ACTUAL Data Instantly From MINI-CIRCUITS At:* ***www.minicircuits.com***

***ISO 9001 ISO 14001** CERTIFIED*

177Rev. E

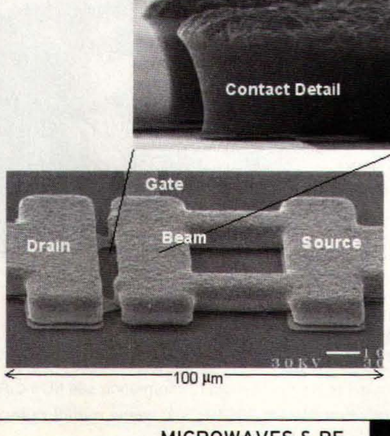
# MEMS Switches Run For 100 Billion Cycles

These rugged MEMS switches offer low insertion loss, high isolation, and high linearity for a variety of commercial and military applications needing high reliability with low current consumption.

**JACK BROWNE**
**Publisher/Editor**

**Microelectromechanical systems (MEMS) technology is coming of age in terms of reliability. The RMSW200 RF MEMS single-pole, single-throw switch offered by RadantMEMS (Stow, MA), for example, has been performance tested at 10 GHz for high reliability even over 100 billion switching cycles. The switch, which is designed for applications from DC to 40 GHz, also shaves insertion loss to a bare minimum** compared to competing technologies, such as PIN-diode-based solid-state switches.

The company's MEMS switches are three-terminal devices that employ a cantilever beam. The switches are fabricated with an all-metal surface micromachining process on high-resistivity silicon. For environmental protection, the switches are hermetically sealed within wafer-scale packaging. A basic RadantMEMS switch configuration consists of a drain, source, gate, and beam **(see figure)**. The beam is deflected by applying a voltage between the gate and source electrodes. The free end of the beam contacts the drain and completes an electrical path between the drain and the source. The company's switches are designed for actuation (gate) voltages from 40 to 120 V. At low frequencies, the on resistance has been measured at less than 1 Ω, while the on-response switching time is about 5 µs.

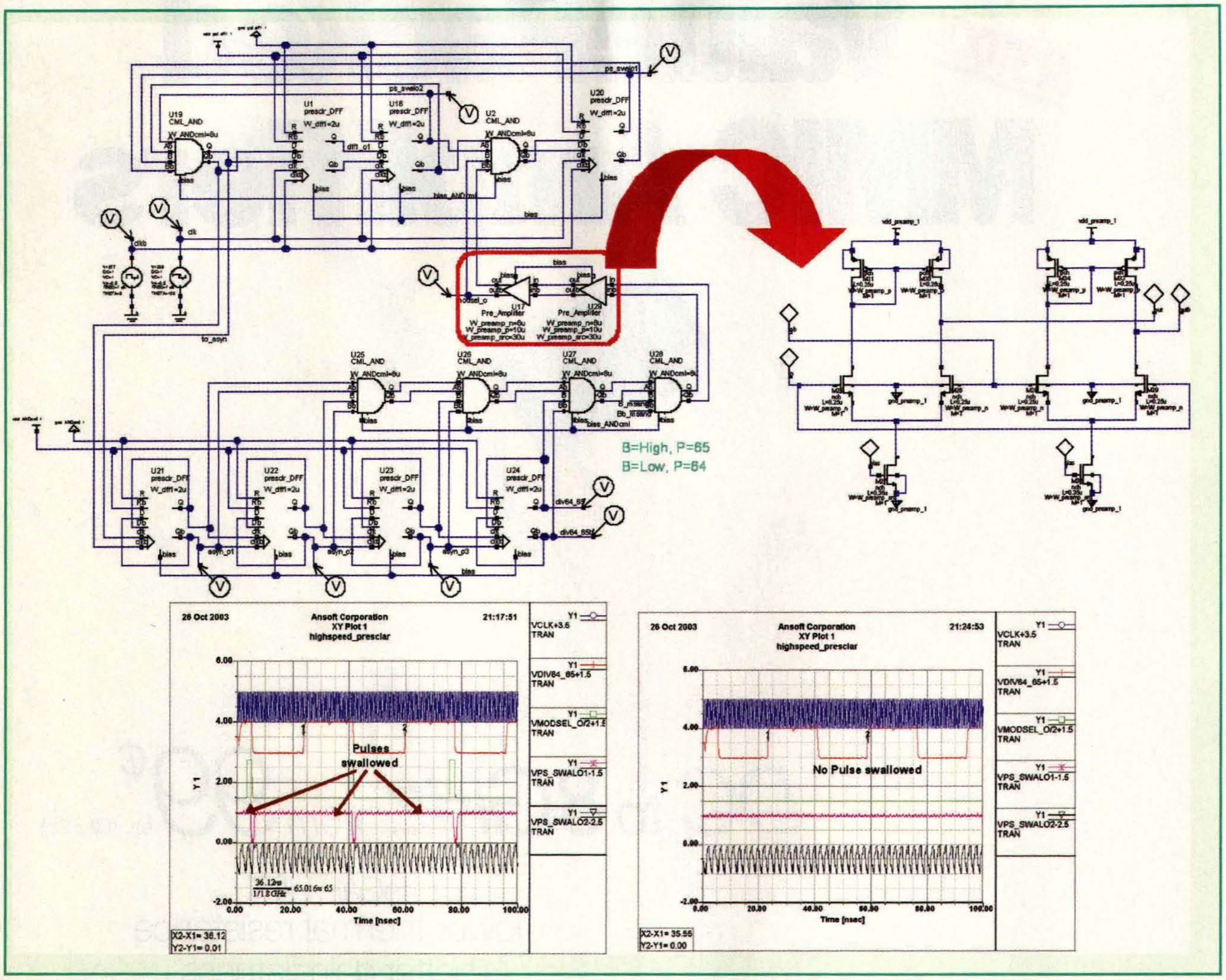



**The MEMS switch's cantilever beam is deflected by applying a voltage between the gate and source electrodes. The free end of the beam contacts the drain and completes the electrical path between the drain and the source.**

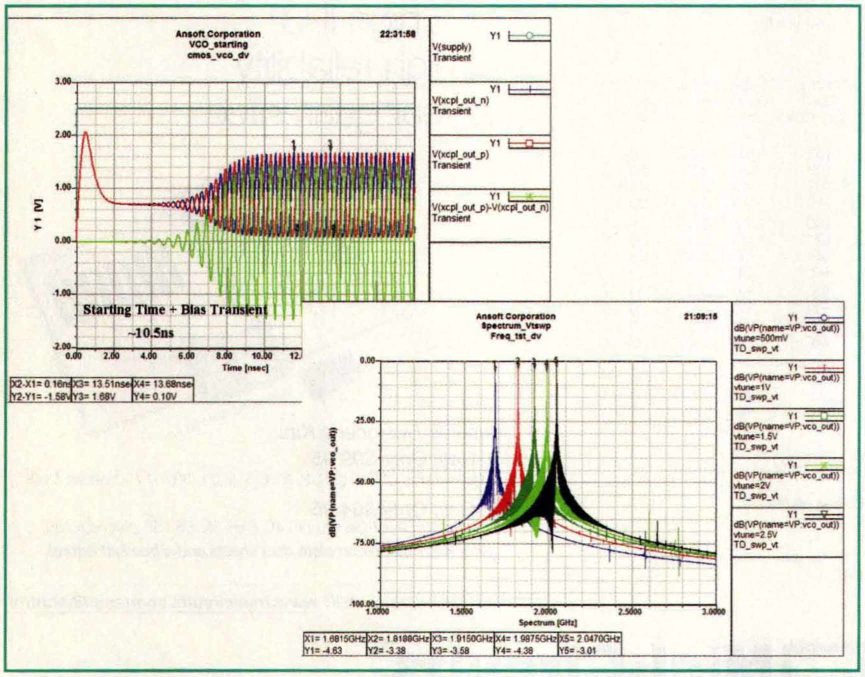
Performance testing conducted on an eight-contact MEMS switch with 0.5-W input power at 10 GHz revealed the device to be perfectly functional when the testing was stopped after 100 billion switching cycles. Both insertion loss and isolation remained stable over the life of the switch. For a switching rate of 1 kHz, the power consumption was a low 5 µW.

The company's DC-to-40-GHz model RMSW200 SPST switch is among the highest-frequency commercial MEMS switches. It features less than 0.5 dB insertion loss to 38 GHz and better than 20 dB return loss to 36 GHz. Insertion loss is typically less than 0.27 dB at 2 GHz. The isolation is 20 dB at 10 GHz and 13 dB at 40 GHz.

The model RMSW100 SPST switch is designed for use from DC to 12 GHz. It features less than 0.15 dB insertion loss at 2 GHz and more than 25 dB isolation at 2 GHz, with better than 30-dB return loss at 2 GHz. **RadantMEMS, 255 Hudson Rd., Stow, MA 01775; (978) 562-3866, FAX: (978) 562-6277, e-mail: sales@radantmems.com, Internet: www.radantmems.com.**




4. Prescaler design performed at the system level using Ansoft Designer's capabilities.




5. Nexxim performs time-domain and frequency-domain analyses on the PLL's VCO using the same netlists and device models.

*(continued from p. 96)*

correct solution to problems that are simple, such as reflections from transmission lines, yet cannot be handled accurately by current tools.

Nexxim represents a new approach to simulation, built from the ground up. It can be invoked from Ansoft Designer to form a complete design capture, simulation and post-processing environment, providing simulation accuracy and transistor-level detail without the use of model approximations. Dynamic parameterized links to HFSS and system co-simulation with Ansoft Designer allow for circuit design, circuit/system co-design and post-layout verification for complex, mixed signal ICs. **Ansoft Corp., 225 West Station Square Dr., Suite 200, Pittsburgh, PA 15219; (412) 261-3200, FAX: (412) 471-9427, e-mail: info@ansoft.com, Internet: www.ansoft.com.** MRF

## Power Amp Supplies Solid EVM Performance

THE RMPA2453 is a linear RF power-amplifier module (PAM)for high-performance wireless-local-area-network

(WLAN) applications in the 2.4-to-2.5-GHz frequency band. Optimized for 802.11b/g applications, the RMPA2453 features Error Vector Magnitude (EVM) performance of 2.5 percent. The RMPA2453 power amplifier internally matches both the input and output to 50 Ω, and provides an on-chip power-sensing detector with dual power-saving shutdown options.

**Fairchild Semiconductor, 82 Running Hill Rd., South Portland, ME 04106; (800) 341-0392 (outside Maine), (800) 832-5505 (inside Maine), (207) 775-8100, Internet: www.fairchildsemi.com.**

## DROs Suit Microwave And Satcom Applications

THE DIELECTRIC RESONATOR OSCILLATOR (DRO) offers a wide range of frequencies in the 1-to-28-GHz range. The key features of DRO are low phase noise of –105 dBc/Hz @ 10 kHz, up to +23 dBm output power, 200 MHz bandwidth, internal voltage stability, and operating temperature range of –45° to 100°C. The DRO is mainly suitable for applications in microwave and satellite communications.

**Princeton Microwave Technology, 3 Nami Lane, Unit C-10, Mercerville, NJ 08619; (609) 586-8140, FAX: (609) 586-1231, Internet: www.princetonmicrowave.com.**

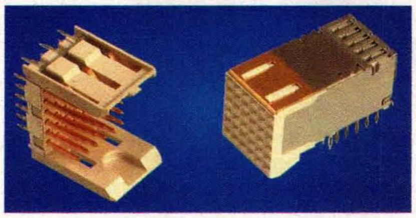
## Library Includes Passive Component Models

VERSION 2.0 of Modelithics' CLR Library™ is comprised of Modelithics' Global Models™ that allow designers to conveniently adjust part value and substrate properties while accounting for high-frequency parasitics and complex interactions between the device, substrate, and solder "pad stack" geometries. Version 2.0 adds many new models, including substrate-scalable Global Models for selected capacitor, inductor, and resistor families from ATC, Presidio, Vishay, Panasonic, Taiyo Yuden, and KOA Speer. The release also includes updates to some existing model families and enables more convenient referencing of substrate information. The CLR Library is available for popular microwave electronic-design-automation (EDA) tools such as Agilent Technologies' Advanced Design System (ADS), Applied Wave Research Microwave Office, and Eagleware GENESYS.

**Modelithics, Inc., 3650 Spectrum Blvd., Suite 170, Tampa, FL 33612; (813) TO-MODEL [(813) 866-6335], e-mail: sales@modelitics.com, Internet: www.modelithics.com.**

## Connectors Provide Backplane Interface

METRAL® 4000 high-speed backplane connectors enable connections between I/O controller modules and Serial ATA (SATA) disk backplanes in servers and enterprise storage enclosures. Power, communication and control signals, and



differential signals for up to 16 SATA ports can be supported by the Metral 4000 connector. The connectors accommodate initial SATA serial data transmission rates of 1.5 Gb/s and anticipate next-generation, high-speed signaling at 3 Gb/s. Metral 4000 receptacles and headers feature press-fit tails for reliable attachment to circuit boards without soldering. P&A: $0.13 per mated contact pair for minimum order quantities. Samples are available for delivery; stock to 8 wks.

**FCI USA, Inc., 825 Old Trail Rd., Etters, PA 17319; (800) 237-2374, e-mail: electronics.us@fciconnect.com, Internet: www.fciconnect.com/highspeed/highspeed_01.asp.**

## Receiver Series Expands To European Frequencies

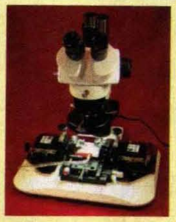
THE 433-MHZ LR RECEIVER interfaces to virtually any data source, including microcontrollers and decoder chips, making them suitable for applications such as remote control, keyless entry, and periodic data transfer. LR receivers are capable of operating at distances in excess of 3000 ft. The modules operate over a 2.7-to-5.2-VDC range and feature low power consumption, wide operational temperature range, adjustable transmitter power, and a receiver sensitivity in excess of –115 dBc. LR Series modules are designed for regulatory compliance and interference immunity and are available in frequencies suitable for both domestic and export wireless applications. P&A: 433-MHz LR receivers are in production and priced at approximately $6.78 in volume production quantities.

**Linx Technologies, Inc., 575 S.E. Ashley Pl., Grants Pass, OR 97526; (541) 471-6256, FAX: (541) 471-6251, Internet: www.linxtechnologies.com.**

## VCO Is Capable Of Very High Modulation Speed

MODEL MW500-1467 VCO provides a clean, stable output of +4 dBm ±0.5 dB with –105 dBc/Hz phase noise @ 100 kHz. Tuning-voltage range is 0.5 to 10 V. Supply is +5 V @ 25 mA, but the VCO will operate with reduced output to +3 V. Custom versions can be supplied with any 200-MHz band within the range of 4.5 to 6.5 GHz. Harmonics are –22 dBc max. The VCO is capable of very high modulation speed.

**Micronetics VCO Product, 28 Hampshire Dr., Hudson, NH 03051; (603) 579-0900, Internet: www.micronetics.com.**



**Laboratory (RF)MicroProbe Station**

*Extremely Low Cost*
*< $10,000 US*
*DC/RF/Microwave Test*

*A ultra compact, manually operated probe station for engineers, scientists and students. Measure Microwave, RF and IV parameters of Semiconductor Devices. Characterize MEMS, wireless, photonic and nanoelectronic components and assemblies.*

*• Benchtop Size($1ft^2$) • 2" Vacuum chuck with pump• 1" X-Y-Ø stage with z-lift•*
*•2 ea. 0.5" X-Y-Z probe positioners, includes 2 ea. 18 GHz probes & DC needles•*
*•10X/30X Stereo Zoom Trinocular Microscope • Flourescent Illuminator •*
*•Compatible with additional Magnetic Mount Positioners(optional)•*
*•Compatible with industry standard microwave probes(optional)•*

***•Cost effective for research projects•***

Jmicro Technology

*J microTechnology*
3744 NW Bluegrass Pl
Portland, OR 97229
(503) 614-9509
(503) 531-9325 [FAX]
www.jmicrotechnology.com

**Research Performance / Student Price**

J MICROTECHNOLOGY

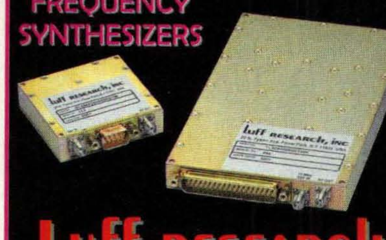
*SIGNAL GENERATORS*

Seven compact, programmable models cover 0.5 to 26.5 GHz with 1 MHz resolution. Prices start at $4,250

April Instrument
Sunnyvale, CA
www.aprilinstrument.com
Tel: (650) 964-8379 Fax: (650) 965-3711

APRIL INSTRUMENTS

FREQUENCY SYNTHESIZERS



**Luff RESEARCH**

**Visit us at: www.luffresearch.com**
**E-mail: sales@luffresearch.com**
**Tel.: (516) 358-2880 Fax: (516) 358-2757**

PHASE-LOCKED OSCILLATORS

LUFF RESEARCH

# PDD

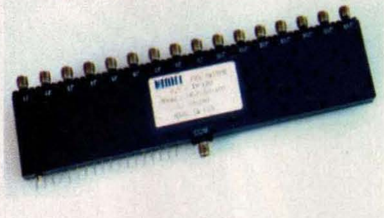
Your Online Resource

For RF and Microwave Products and Manufacturers

If you need a part, you'll find it at:

**www.m-rf.com**

SP16T Pin-Diode Switch (0.5-18 Ghz)



UMCC's Model SR-U010-16S is an absorptive sixteen-throw solid state switch operating over 0.5-18 Ghz. Switch features: 7.0 dB loss / 60dB Isolation at 18 Ghz, 2:1 VSWR, 25ns Rise/Fall time, +5/-12 VDC Supplies, CMOS or TTL controls, all removable connectors. Unit measures 1.6" x 8.0" x 0.4".

**Product Line:**

- **Solid State Variable Attenuators**
- **DC-Blocks, Bias Tee's, Transformers**
- **Directional Couplers**
- **Hybrid Couplers (90°/180°)**
- **Power Dividers / Combiners**
- **Solid State Switches**
- **Special Function Subsystems**

**Universal Microwave Components Corporation**
5702-D General Washington Drive
Alexandria, Virginia 22312
Tel: (703) 642-6332 , Fax: (703) 642-2568
Email: UMCC@ UMCC111.Com
Web: www.umcc111.com

UMCC

UNIVERSAL MICROWAVE

LDMOS Power

LR301 300 Watts
CW To 350MHz
Pulsed to 500MHz

polyfet rf devices
Contact / View us on the WEB at
http://www.polyfet.com
YOUR POWER MOSFET PEOPLE

POLYFET RF DEVICES

**Wireless Product Development**

*The "Part 15" Experts*
*UHF, 915 MHz, 2.4 GHz*

**Two Way Data**
- Spread Spectrum Data Modems
- Bluetooth™
- RFID
- Narrow Band Links

**One Way Data**
- Resource Management
- Instrumentation
- Security
- Tracking

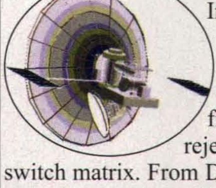
**APEX**
WIRELESS, INC.

*Standard Products*
*Product Development*
*Licensing*

2525 Frontier Ave., Suite 200, Boulder, CO 80301
(303) 443-6699, EXT. 26 FAX (303) 442-7123
e-mail: rf@apexwireless.com www.apexwireless.com

APEX WIRELESS

***LUNA Microwaves, Inc.***
*Manufacturers of Electronic Wave Filters*



LUNA Microwaves, Inc., offers a complete line of RF & Microwave filters, diplexer, switch filter banks Band reject tunable filters, switch matrix. From DC - 40GHz. For more information call @301-9264728
7610 Rickenbacker Dr.,
Gaithersburg MD 20879
Tel. 301-926-4728, Fax 301-926-4729
e-mail: aluna74@hotmail.com

LUNA MICORWAVES INC.

**Manual Probe Station**

*Very Low Cost*
*High Function*
*6" or 8" Chuck*

*A full featured, modestly priced, manually operated probe station developed for engineers and scientists.*
*Measure Microwave, RF and DC parameters of Semiconductor Devices, Packages and Assemblies with NIST traceability .*

*• Benchtop Size($<3ft^2$) • Vacuum chuck • Slide out X-Y-Ø stage•*
*•X-Y-Z probe positioners •Top Plate Z-lift •Vacuum Accessory Manifold•*
*•6.5X-112.5X Stereo Zoom Microscope • Adjustable Halogen Illuminator •*
*•Vacuum Accessories • Compatible with 40GHz+ probes•*
*• Accessories for Thermal Chucks and Probe Cards•*
*•Compatible with Magnetic Mount Positioners•*

*•Test wafers, microstrip packages and surface mount components•*

Jmicro Technology

*J microTechnology*
3744 NW Bluegrass Pl
Portland, OR 97229
(503) 614-9509
(503) 531-9325 [FAX]
www.jmicrotechnology.com

**A Precision Probe Station at a Utility Price**

J MICROTECHNOLOGY

| Advertiser | Website, E-Mail Address | Page |
|---|---|---|
| **A** | | |
| Advanced Power Technology RF | www.advancedpower.com | 36 |
| AEA Wireless Inc | www.aea-wireless.com | 38 |
| Aeroflex Inmet | www.aeroflex-inmet.com | 25 |
| Agilent Epsg | www.agilent.com/find/mistakes | Cov 2 |
| ALK Engineering | www.alkeng.com | 112 |
| Amplifier Research | www.ar-worldwide.com | 65 |
| American Technical Ceramics | www.atceramics.com | 9 |
| Anritsu Company | www.us.anritsu.com/navigator/126 | 93 |
| Ansoft Inc | www.ansoft.com/whatsnexxt | 45 |
| Ansoft Inc | www.ansoft.com/solveit | 46-47 |
| Analog Devices | www.analog.com/AgileRF | 63 |
| Anaren Microwave Inc | www.anaren.com | COV 4 |
| April Instruments | www.aprilinstrument.com | 109 |
| Apex Wireless Inc | www.apexwireless.com; e-mail: rf@apexwireless.com | 109 |
| Arra Inc. | www.arra.com; e-mail: sales@arra.com | COV 3 |
| Avtech Electrosystems Ltd. | www.avtechpulse.com; e-mail: info@avtechpulse.com | 38 |
| **B** | | |
| Bookham JCA | www.bookhamjca.com; e-mail: sales@bookhamjca.com | 2 |
| **C** | | |
| Ciao Wireless Inc | www.ciaowireless.com; e-mail: sales@ciaowireless.com | 17 |
| Coilcraft | www.order.coilcraft.com | 10 |
| Compac | www.compac-rf.com | 86 |
| Computer Simulation Technology | www.cst.com | 8 |
| Corning Frequency Control | www.corningfrequency.com | 87 |
| Cougar Components | www.cougarcorp.com | 21 |
| **D** | | |
| Daico Industries Inc. | www.daico.com | 66 |
| DBM,LLC | www.dbmcorp.com | 78 |
| Delta Electronics Mfg | www.DeltaRF.com | 3 |
| Diamond Engineering | www.MicrowaveRF.com; e-mail: www.diamondeng.net | 110 |
| Ditom Microwave Inc. | www.ditom.com; e-mail: sales@ditom.com | 77 |
| **E** | | |
| Eagleware | www.eagleware.com | 32 |
| Elcom Technologies | www.elcom-tech.com | 16 |
| EM Research Inc | www.emresearch.com; e-mail: sales@emresearch.com | 19 |
| **F** | | |
| Focus Microwave | www.focus-microwaves.com; e-mail: info@focus-microwaves.com | 75 |
| Frequency Electronics Inc. | www.freqelec.com; e-mail: sales@freqelec.com | 44 |
| **G** | | |
| Greenray Industries Inc | www.greenrayindustries.com; e-mail: sales@greenrayindustries.com | 96 |
| **H** | | |
| Herley-CTI | www.herley.com; e-mail: sales@herley-cti.com | 41 |
| Herotek Inc | www.herotek.com; e-mail: info@Herotek.com | 74 |
| Hittite Microwave | www.hittite.com | 51 |
| Huber & Suhner, Inc. | www.hubersuhnerinc.com | 59 |
| **I** | | |
| Interad Ltd | www.interadlimited.com; e-mail: sales@interadlimited.com | 18 |
| **J** | | |
| J Microtechnology | www.jmicrotechnology.com | 109 |
| J Microtechnology | www.jmicrotechnology.com | 109 |
| J Microtechnology | www.jmicrotechnology.com | 110 |
| Johanson Technology, Inc. | www.johansontechnology.com | 88 |
| **K** | | |
| K&L Microwave/Dover | www.klmicrowave.com | 6 |
| KW Microwave Corp | www.kwmicrowave.com | 98 |
| **L** | | |
| Lemos International Co Inc | www.lemosint.com; e-mail: sales@lemosint.com | 58 |
| Linx Technologies | www.antennafactor.com | 110 |
| Linear Technology Corporation | www.linear.com | 79 |
| Luna Microwaves Inc | e-mail: aluna74@hotmail.com | 109 |
| Luff Research | www.luffresearch.com; e-mail: sales@luffresearch.com | 109 |
| **M** | | |
| Maxim Integrated Products | www.maxim-ic.com | 83 |
| Maxim Integrated Products | www.maxim-ic.com | 32A-X |
| Marki Microwave Inc | www.markimicrowave.com/m3h-0209.com; e-mail: mixers@markimicrowave.com | 12 |
| Maury Microwave Inc | www.maurymw.com; e-mail: maury@maurymw.com | 37 |
| Meca Electronics Inc | www.e-meca.com | 73 |
| Merrimac Industries Inc | www.merrimacind.com | 69 |
| Mid-Atlantic RF Systems Inc | www.midatlanticrf.com; e-mail: info@midatlanticrf.com | 50 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 14-15 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 30-31 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 55 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 53 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 61 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 91 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 35 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 49 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 27 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 107 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 71 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 89 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 99 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 103 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 105 |
| Mini-Circuits/SCI Components | www.minicircuits.com | 101 |
| Micronetics Wireless | www.micronetics.com | 95 |
| Midwest Microwave | www.midwest-microwave.com; e-mail: sales@midwest-microwave.com | 29 |
| Microwave Solutions, Inc. | www.microwavesolutions.com; e-mail: sales@microwavesolutions.com | 64 |
| MITEQ MEDIA | www.miteq.com | 1 |
| MITEQ MEDIA | www.miteq.com | 11 |
| **N** | | |
| Narda An L-3 Communications | www.nardamicrowave.com; e-mail: nardaeast@L-3com.com | 4 |
| Nexyn Corporation | www.nexyn.com | 52 |
| Nemal Electronics Intl Inc | www.nemal.com; e-mail: info@nemal.com | 11 |
| Noisecom | www.noisecom.com/cal. | 7 |
| **P** | | |
| Phonon Corporation | www.phonon.com; e-mail: saw@phonon.com | 86 |
| Picosecond Pulse Labs, Inc. | www.picosecond.com/comb | 82 |
| Polyfet RF Devices | www.polyfet.com | 109 |
| **R** | | |
| RFHIC Company | www.rfhic.com; e-mail: rfsales@rfhic.com | 60 |
| Rockwell Scientific | www.rockwellscientific.com | 70 |
| **S** | | |
| Sawtek, a Triquint Company | www.triquint.com; e-mail: info-sawtek@tqs.com | 39 |
| San-tron Inc. | www.santron.com; e-mail: sales@santron.com | 20 |
| Sonnet Software Inc | www.sonnetsoftware.com | 76 |
| Sophia Wireless Inc | www.sophiawireless.com | 34 |
| Stealth Microwave | www.stealthmicrowave.com; e-mail: sales@stealthmicrowave.com | 68 |
| Synergy Microwave | www.synergymwave.com; e-mail: sales@synergymwave.com | 43 |
| Synergy Microwave | www.synergymwave.com; e-mail: sales@synergymwave.com | 81 |
| Synergy Microwave | www.synergymwave.com; e-mail: sales@synergymwave.com | 85 |
| **T** | | |
| Taconic Advanced Dielectric | www.taconic-add.com | 72 |
| Thermoptics | www.thermoptics.com | 18 |
| Triquint Semiconductor, Inc. | www.triquint.com; e-mail: info-sales@tqs.com | 39 |
| TTE Incorporated | www.tte.com | 13 |
| **U** | | |
| Universal Microwave Components | www.umcc111.com; e-mail: UMCC@UMCC111.Com | 109 |
| **W** | | |
| WJ Communications | www.wjcom; e-mail: sales@wj.com | 22 |
| **X** | | |
| XMA Corporation | www.xmacorp.com | 70 |
| **Z** | | |
| Zeland Software Inc | www.zeland.com; e-mail: zeland@zeland.com | 24 |

*Domestic Edition only  **International Edition only  *This index is provided as an additional service by the publisher, who assumes no responsibility for errors or omissions.*

## MARKETING AND ADVERTISING STAFF


**GROUP PUBLISHER**
Craig Roth
(201) 845-2448
e-mail:croth@penton.com

**SALES ASSISTANT**
Judy Kollarik
(201) 845-2427
e-mail: jkollarik@penton.com

**DIRECT CONNECTION ADS CLASSIFIED ADVERTISING**
Joanne Reppas
(201) 666-6698
e-mail: jrepfrangides@msn.com

**CIRCULATION CUSTOMER SERVICE (LIVE)**
Phone: (847) 763-9670
Fax: (847) 763-9673
e-mail: microwaves&rf@halldata.com

**NEW YORK, NEW ENGLAND, SOUTHEAST, MID ATLANTIC, DC, VA,**
Paul Barkman
Global Sales Manager
Penton Media, Inc.
45 Eisenhower Dr., fifth floor
Paramus, NJ 07652
(908) 704-2460
FAX: (908) 704-2486
e-mail: pbarkman@penton.com

**MIDWEST, SOUTHWEST, WESTCOAST, NORTHWEST, CANADA**
Michael Barkman
Account Executive
Penton Media, Inc.
45 Eisenhower Dr., fifth floor
Paramus, NJ 07652
(908) 832-6551
FAX: (908) 832-7052
e-mail: mbarkman@penton.com

**GERMANY, AUSTRIA, SWITZERLAND**
Friedrich K. Anacker
Managing Director
InterMedia Partners GmbH (IMP)
In der Fleute 46
D-42389 Wuppertal
Germany
Phone: 011-49-202-271-690
FAX: 011-49-202-271-6920

**FRANCE**
Emmanual Archambeaud
Defense & Communication
48 Bd Jean-Jaures,
92110 Clichy
France
Phone: 33-01-47-30-7180
FAX: 33-01-47-30-0189

**TAIWAN, R.O.C.**
Charles C.Y. Liu, President
Two-Way Communications Co., Ltd.
11F/1, No. 421
Sung Shan Road
Taipei 110, Taiwan, R.O.C.
Phone: 886-2-2727-7799
FAX: 886-2-2728-3686

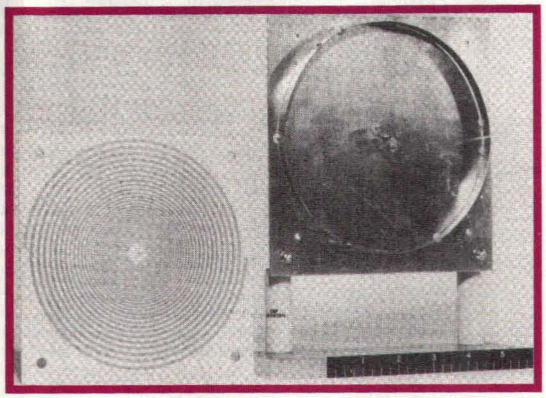
**JAPAN**
Hiro Morita
Japan Advertising
Communications, Inc.
Three Star Building
3-10-3 Kanda Jinbocho
Chiyoda-ku, Tokyo 101-0051, Japan
Phone: 81-3-3261-4591
FAX: 81-3-3261-6126


**Subscription Assistance and Information:**


Microwaves & RF (ISSN 0745-2993) is published monthly, except semi-monthly in December. Microwaves & RF is sent free to individuals actively engaged in high-frequency electronics engineering. In addition, paid subscriptions are available. Subscription rates for U.S. are $90 for 1 year ($115 in Canada, $145 for International). Published by Penton Media, Inc., The Penton Building, 1300 E. 9th St., Cleveland, OH 44114-1503. Periodicals Postage Paid at Cleveland, OH and at additional mailing offices. POSTMASTER: Send change of address to: Penton Media Inc., P.O. Box 2095, Skokie, IL 60076-7995. For paid subscription requests, please contact: Penton Media Inc., P.O. Box 2135, Skokie, IL 60076-7835. Publications Mail Agreement No. 40026880. Return Undeliverable Canadian Addresses to: Circulation Dept. or DPGM, 4960-2 Walker Road, Windsor, ON N9A 6J3. Canadian GST# R126431964. International editions are shipped via several entry points, including: Editeur Responsable (Belgique), Vuurgatstraat 92, 3090 Overijse, Belgique.

**Back issues of MicroWaves and *Microwaves & RF* are available** on microfilm, microfiche, 16-mm, or 35-mm roll film. They can be ordered from Proquest Information and Learning Periodicals Acquisitions, PO Box 1346, Ann Arbor, MI, 48106-1346. For immediate information, call (313) 761-4700.

# looking back



MORE THAN 32 YEARS AGO, researchers at the US Army Electronics Command (Belmar, NJ) pursuing low-voltage traveling-wave tubes (TWTs) revealed the feasibility model of a printed-circuit TWT with two spiral circuits enclosing an emitter-collector structure to form a vacuum.

# next month

## Microwaves & RF August Editorial Preview

## Issue Theme: Wireless Applications

### News

August interrupts the "dog days" of summer with a special report on Broadband Technologies. As the general public increases its appetite for instant Internet access and the ability to download large files or view streaming video, the RF/microwave world must cope with methods of providing broader bandwidths and more efficient use of available spectrum. This report will examine the current push in wireless-local-area-network (WLAN) standards for higher-data-rate performance (to 100 Mb/s and beyond) as well as the growing number of companies pursuing broadband solutions for wireless voice, data, and video using ultra-wideband (UWB) techniques.

### Design Features

August continues one of the most ambitious multipart projects ever to appear in this magazine: an eight-part design-feature collection on amplifier design. The author, Dr. Joseph White of JFW Technology, promises that all who read the entire series will be ready and able to design their own microwave amplifier. Additional articles in August will support the wireless broadband theme with a report in generating UWB arbitrary waveforms by means of optical spectrum sculpting, details on the next generation of logarithmic amplifiers for wide-dynamic-range commercial and military receivers, and a study on how random noise contributes to timing jitter in high-speed communications systems.

### Product Technology

August unveils the latest technology in flexible, multilayer printed-circuit-board (PCB) materials and bonding films. These low-dielectric-constant substrates feature uniform characteristics with time and temperature and provide the foundation for the next generation of compact, three-dimensional RF and microwave circuits. The August issue will also feature some of the latest products based on microelectromechanical-systems (MEMS) technology as well as a line of high-performance synthesizers suitable for commercial wireless and broadband military wireless applications.